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IRON AND STEEL ENGINEER

VOL. XV AUGUST • 1938 NO. VIII

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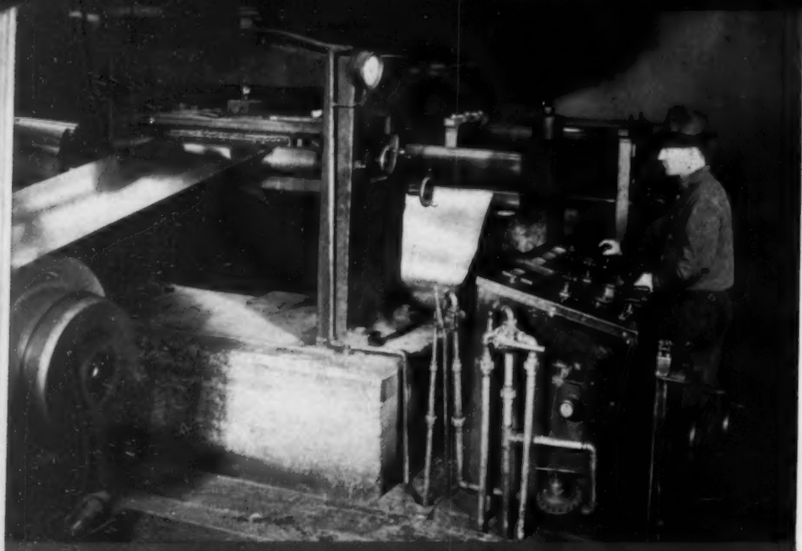
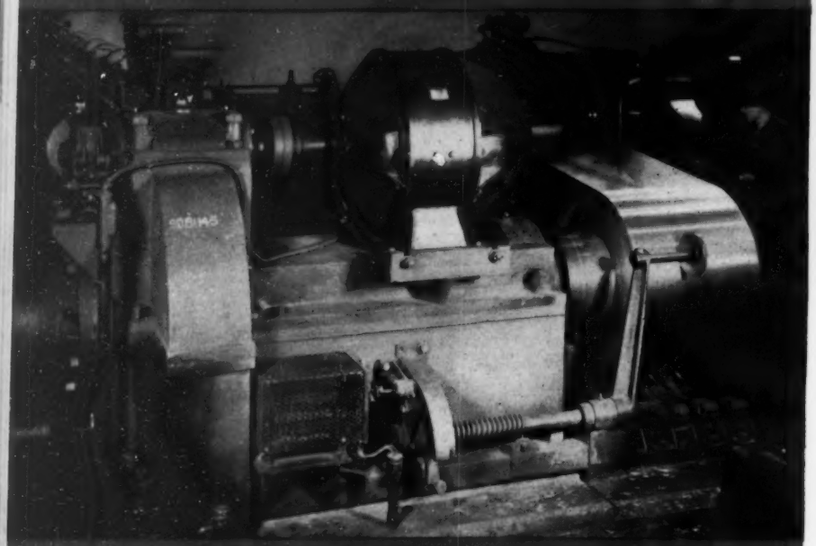
Published Monthly by
ASSOCIATION OF IRON AND STEEL ENGINEERS
Entered as second-class matter January 25th, 1924, at Pittsburgh, Pa., under the Act of March 3rd, 1879. Single Copy $1.50
Subscription price in U. S. & Canada ..... $7.50 per year
Subscription price in foreign countries ..... $10.00 per year

PLASTIC BINDING U. S. PATENT NO. 1970295 LICENSE NO. 51



Delivery end of cleaning line—operator's control bench.



Cleaning line delivery end, showing coiler motor and coil rider device to adjust motor speed for increasing coil diameter.

Cleaning line control board.

They wanted matched to

SO THEY SPECIFIED

Steel mill engineers recognize importance of auxiliary equipment in maintaining schedules, cutting costly "down time," and improving production.

• • •

Whether it be for main drives or for the all-important auxiliaries, Westinghouse matches electrical equipment to the job. An example of this is in the installation of Westinghouse drives and control for cleaning lines, side trim-

Westinghouse

34th

ANNUAL CONVENTION

and IRON AND STEEL EXPOSITION

ASSOCIATION OF IRON AND STEEL ENGINEERS

Cleveland

PUBLIC AUDITORIUM, CLEVELAND, OHIO

Tentative Program

SEPTEMBER 27 - 28 - 29 - 30, 1938

All ACTIVITIES

Tuesday, September 27

9:00 A. M.

Main Lobby

REGISTRATION

CHAIRMAN
FRANK W. LORIG,
Chief Draftsman,
American Steel and Wire Company,
Cleveland, Ohio.

VICE CHAIRMAN
THOMAS B. MCELRAY,
Superintendent Electrical Department,
Carnegie-Illinois Steel Corporation,
Youngstown, Ohio.

9:15 A. M.

BUSINESS SESSION

Club Room B

CHAIRMAN
LOUIS F. COFFIN,
Superintendent Mechanical Department,
Bethlehem Steel Company,
Sparrows Point, Maryland.

VICE CHAIRMAN
JAMES L. MILLER,
Assistant Chief Combustion Engineer,
Republic Steel Corporation,
Cleveland, Ohio.

Annual Meeting and Business Session of Association of Iron and Steel Engineers.

9:30 A. M.

Club Room B

ELECTRICAL ENGINEERING DIVISION

CHAIRMAN
JOHN W. BATES,
Electrical Engineer,
Const. Eng. Div.
Carnegie-Illinois Steel Corp.,
Pittsburgh, Pa.

VICE CHAIRMAN
FRED O. SCHNURE,
Electrical Superintendent,
Bethlehem Steel Co.,
Sparrows Point, Md.

"A Study of the Requirements of 440-Volt, A-C Motor Control for Steel Mills" by Donald C. Nelson, Assistant Electrical Engineer, and J. Russell Powell, General Foreman, Jones and Laughlin Steel Corporation, Pittsburgh, Pennsylvania.

"Performance of Slabbing Mill Auxiliary Drives with Ward-Leonard Control" by W. A. Perry, Superintendent, Electric and Power Departments, Inland Steel Company, and W. B. Snyder, Industrial Engineering Department, General Electric Company.

Official Opening—Iron and Steel Exposition 1:30 P. M.

1:30 P. M.

Club Room B

METALLURGICAL AND WELDING ENGINEERING DIVISION

CHAIRMAN
CHARLES L. MCGRANAHAN,
Assistant General Superintendent,
Jones and Laughlin Steel Corporation,
Pittsburgh, Pa.

VICE CHAIRMAN
JOHN S. KENNEY,
Superintendent Cold Strip Mills,
Wheeling Steel Corporation,
Yorkville, Ohio.

"Continuous Pickling of Wide Strip Steel with Flash Welding" by L. R. Milburn, Engineer, Great Lakes Steel Corporation, Ecorse, Michigan.

2:30 P. M.

METALLURGICAL ENGINEERING DIVISION

"Electrolytic Pickling of Strip Steel" by H. W. Neblett, Engineer, Inland Steel Company, East Chicago, Indiana.

"Pickling of Strip Steel From the Metallurgical Point of View" by H. P. Munger, Metallurgist, Republic Steel Corporation, Warren, Ohio.

WELDING ENGINEERING DIVISION

Club Room A

CHAIRMAN
G. A. HUGHES,
Electrical Engineer,
Truscon Steel Company,
Youngstown, Ohio.

VICE CHAIRMAN
WRAY DUDLEY,
Electrical Superintendent,
National Tube Company,
McKeesport, Pennsylvania.

"European Welding Practice and American Trends" by C. H. Jennings, Research Engineer, Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pennsylvania.

"Welding as Used in Industrial Plants" by Dr. Gilbert Doan, Lehigh University, Bethlehem, Pennsylvania.

VISIT THE IRON AND STEEL EXPOSITION

2:00 - 5:00 P. M.

LADIES CARD PARTY AND TEA

Hotel Statler

7:00 P. M.

VISIT TO IRON AND STEEL EXPOSITION

10:00 P. M.

EXHIBITORS' DANCE—INFORMAL

Hotel Statler—Euclid Ballroom

Wednesday, September 28

9:00 A. M.

Club Room B

MECHANICAL ENGINEERING DIVISION

CHAIRMAN
J. A. CLAUSS,
Chief Engineer,
Great Lakes Steel Corporation,
Ecorse, Michigan.

VICE CHAIRMAN
R. R. THOMAS,
Assistant Chief Engineer,
Tennessee Coal, Iron and Railroad Company,
Ensley, Alabama.

"Finishing Equipment for Wide Strip Mills" by John L. Young, Manager Machinery Sales, United Engineering and Foundry Company, Pittsburgh, Pennsylvania.

"Modern Blooming Mill Design" by Lorenz Iversen, President, Mesta Machine Company, Pittsburgh, Pennsylvania.

1:00 P. M.

Inspection Trip: 98" Hot and Cold Strip Mill, Republic Steel Corporation, Cleveland, Ohio. Buses will depart from the Cleveland Public Auditorium.

2:00 P. M.

LADIES' SIGHT-SEEING TRIP

VISIT THE IRON AND STEEL EXPOSITION
Exposition open from 10 A. M. to 10 P. M.

E S U N D E R *One* R O O F

Thursday, September 29

9:00 A. M.

Club Room B

ELECTRICAL ENGINEERING DIVISION

CHAIRMAN	VICE CHAIRMAN
GEORGE R. CARROLL, Assistant Maintenance Superintendent, Jones and Laughlin Steel Corporation, Aliquippa, Pennsylvania.	W. A. PERRY, Superintendent Electric and Power Departments, Inland Steel Company, East Chicago, Indiana.

"Acceleration of Tandem Cold Strip Mills" by T. R. Rhea and M. J. Leding, Engineers, General Electric Company.

"Low Voltage Rectifiers for Industrial Requirements" by G. E. Stoltz, Manager, Metal Working Section, Westinghouse Electric & Mfg. Company, and J. H. Cox, Manager, Rectifier Engineering Department, Westinghouse Electric & Mfg. Company, East Pittsburgh, Pennsylvania.

9:00 A. M.

Club Room A

COMBUSTION ENGINEERING DIVISION

CHAIRMAN	VICE CHAIRMAN
M. J. CONWAY, Fuel Engineer, Lukens Steel Company, Coatesville, Pennsylvania.	F. E. LEAHY, Fuel Engineer, Youngstown Sheet and Tube Company, Youngstown, Ohio.

"Standardization of Steel Plant Fuel Accounting and Test Procedure for Fuel Consumption Determination" by H. V. Flagg, Combustion Engineer, American Rolling Mill Company, Middletown, Ohio.

"Oil Burning and Its Control" by A. J. Fisher, Fuel Engineer, Bethlehem Steel Company, Sparrows Point, Maryland.

"Use of Mixed Gases for Steel Mill Operations" by E. T. W. Bailey, Combustion Engineer, Steel Company of Canada, Ltd., Hamilton, Ontario, Canada.

2:00 P. M.

Club Room A

LUBRICATION ENGINEERING DIVISION

CHAIRMAN	VICE CHAIRMAN
C. C. PECU, Lubrication Engineer, Bethlehem Steel Company, Lackawanna, New York.	FRANK THOMAS, Lubrication Engineer, Republic Steel Corporation, Cleveland, Ohio.

"Design and Lubrication of Gears and Pinions" by Clark Johnson, Manager, Gear Department, United Engineering and Foundry Company, Pittsburgh, Pennsylvania.

"American and European Lubrication Practice for Steel Mills" by R. M. Gordon, Gordon Lubricators Division, Blaw--Knox Company, Pittsburgh, Pennsylvania.

"Lubricants for Modern Continuous Rolling Mills" by L. Ballard, Supervising Industrial Engineer, Tide Water Associated Oil Company, New York, New York.

2:00 P. M.

Club Room B

MECHANICAL ENGINEERING DIVISION

CHAIRMAN	VICE CHAIRMAN
H. G. R. BENNETT, Assistant General Superintendent, Carnegie-Illinois Steel Corporation, Duquesne, Pennsylvania.	C. P. BETZ, Superintendent Coke Plant, Hanna Furnace Division, Great Lakes Steel Corporation, Ecorse, Michigan.

"Design and Operation of the Modern Blast Furnace" by J. C. Barrett, Carnegie-Illinois Steel Corporation, Youngstown, Ohio.

"Modern Coke Oven Design and Practice" by Fred Denig, Vice President, Engineering and Construction Division, Koppers Company, Pittsburgh, Pennsylvania.

VISIT THE IRON AND STEEL EXPOSITION
Exposition open from 10 A. M. to 5:30 P. M.

6:30 P. M.

FORMAL BANQUET AND DANCE

Hotel Statler.

Main Ball Room

SPEAKERS—T. M. GIRDLER, Chairman of the Board, Republic Steel Corporation, and "SENATOR" EDWARD FORD, New York City.

Friday, September 30

9:00 A. M.

Inspection Trip: Fisher Body Plant, General Motors Corporation, Cleveland, Ohio. Buses will depart from Cleveland Public Auditorium.

VISIT THE IRON AND STEEL EXPOSITION
Exposition Open From 10 A. M. to 4 P. M.

PERTINENT DETAILS

All of the events of the Convention and Exposition, with the exception of the social functions, will be held in the Cleveland Public Auditorium. This is in line with the policy the Association has been seeking to maintain at its Annual Conventions, in having all activities under the one roof. The Inspection Trips which will be held to Republic Steel Corporation's new hot strip mill, and the Cleveland Plant of the Fisher Body Company will depart from the Public Auditorium. The social affairs will all be held at the Hotel Statler, which will be the headquarters Hotel.

Iron & Steel Exposition

SPONSORED BY

ASSOCIATION OF IRON AND STEEL ENGINEERS

CLEVELAND PUBLIC AUDITORIUM, CLEVELAND, OHIO

SEPTEMBER 27 - 28 - 29 - 30, 1938

THE annual Iron and Steel Exposition which will be held in conjunction with the Annual Convention of this Society promises to be of considerable interest to all the steel mill executives and operating men. Approximately 100 manufacturers of steel mill equipment will utilize 25,000 square feet of space in the exhibit halls to display their latest designs of equipment. One of the features of this exposition will be the animated model of the Youngstown Sheet & Tube Company's new seamless tube mill. This display will be jointly sponsored by this Company and the Aetna-Standard Engineering Company. From advance information, this coming Iron and Steel Exposition will be one which few steel men can afford to miss.

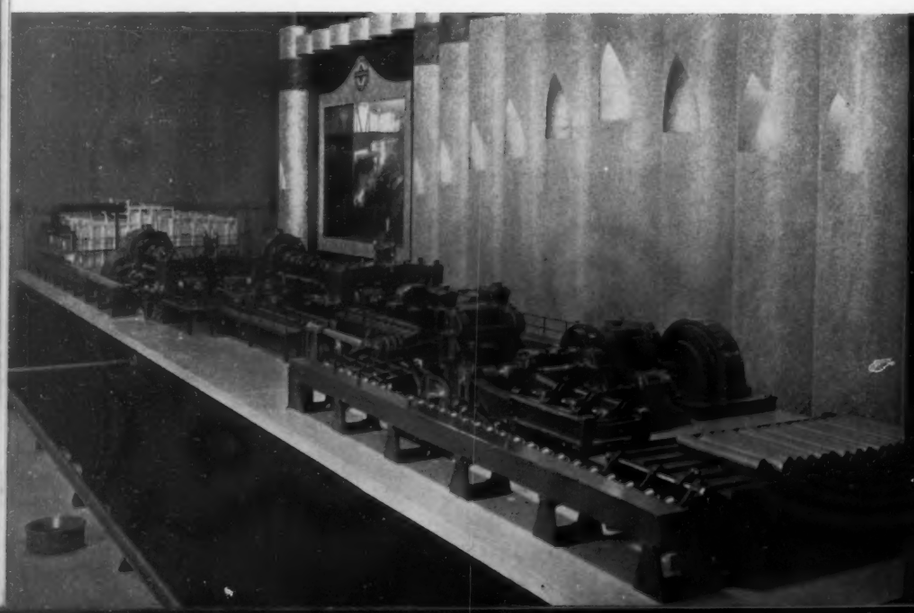
EXPOSITION HOURS

TUESDAY, SEPT. 27— 1:30 P. M. to 5:30 P. M.
7:00 P. M. to 10:00 P. M.

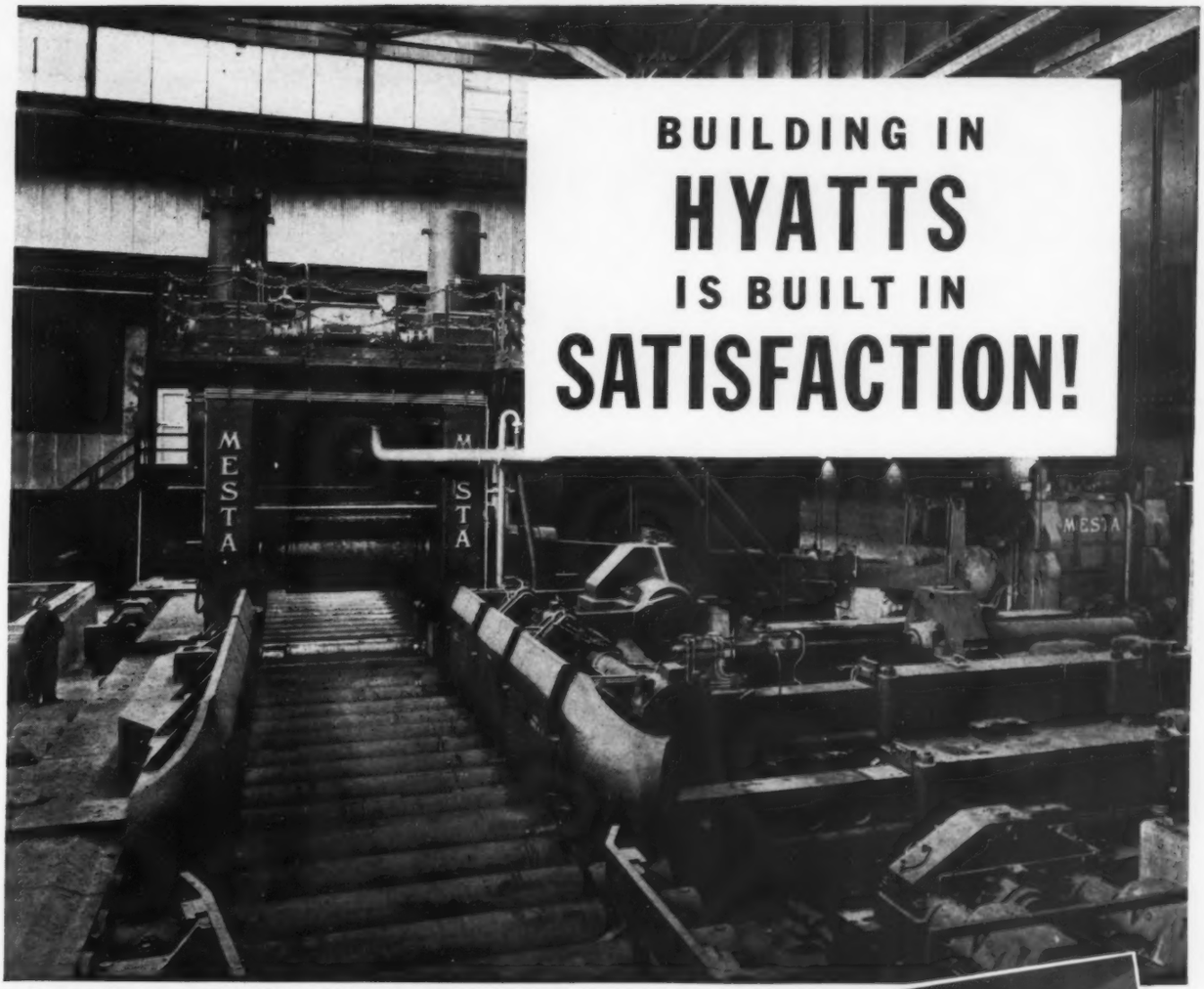
WEDNESDAY, SEPT. 28—10:00 A. M. to 10:00 P. M.

THURSDAY, SEPT. 29—10:00 A. M. to 5:30 P. M.

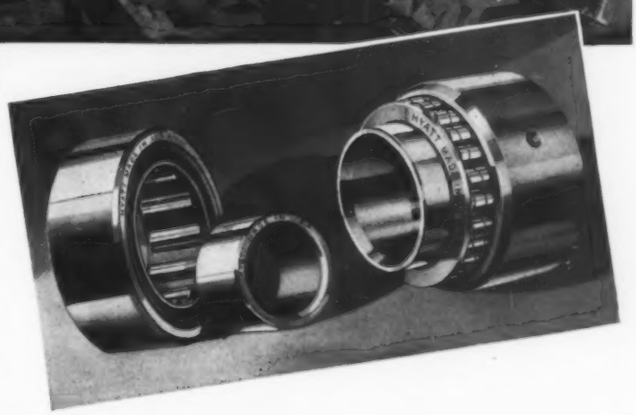
FRIDAY, SEPT. 30—10:00 A. M. to 4:00 P. M.



At left is shown a view of a model of the Youngstown Sheet and Tube Company's new seamless tube mill. This model tube mill which will be on display at the Iron and Steel Exposition, is constructed on a scale of one inch to a foot. The plans for this model mill were converted into proper scale from the original drawings by employees of the Company.



● This new Hyatt equipped **MESTA 46" Blooming Mill** was recently put into operation at the Great Lakes Steel plant. Again indicating the predominance of Hyatts for tough operations.



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HYATT
ROLLER BEARINGS

A New METAL ROLLING Process ... ITS THEORY and OPERATION

By FRANK R. KRAUSE

CONSULTING ENGINEER

ELLWOOD CITY, PENNA.

▲ DURING the past year development work has been progressing on a new type rolling mill which promises far reaching changes for the steel industry. This mill has many new features and the results obtained with it to date are startling.

The usefulness of the new method of rolling has been experimentally proven by operations of a mill in Ellwood City, Pennsylvania, where strip steel was cold rolled from 4″ to 12″ widths from bars ⅛ to ⅜″ in thickness by 20 feet long.

Typical reductions and elongations obtained by the process were as follows:

Low Carbon Strip Steel ¼″ Thick Reduced to .015″ (Elong. 16:1)

Low Carbon Strip Steel ⅜″ Thick Reduced to .088″ (Elong. 4:1)

Copper Bar ⅜″ Thick Reduced to .088″ (Elong. 4:1)

18–8 Stainless Steel .200″ Thick Reduced to .019″ (Elong. 10:1)

17 Chrome Steel 5/16″ Thick Reduced to .024″ (Elong. 8:1)

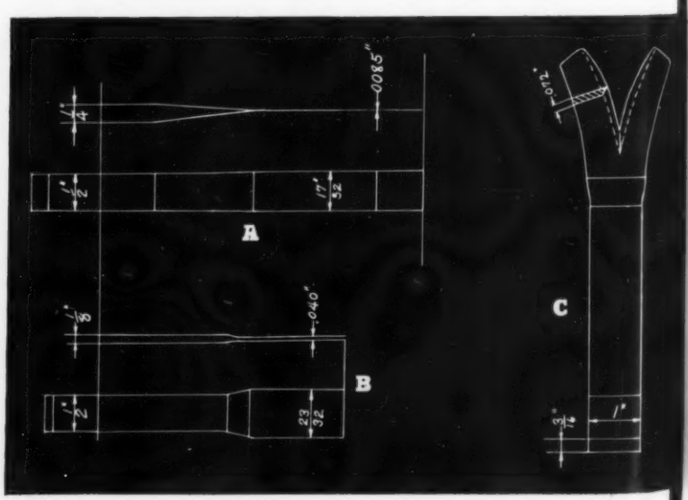
These reductions are not the limits which can be obtained with this process. Available power and the design of this experimental mill limit the reductions when widths from 8 to 12″ are rolled. However, 3/16 x 8″ widths have been rolled to .018″ and 3/16 x 12″ widths to .025″.

To show a comparison in spreading and how far the reductions may be extended without any deleterious effects on the metal, a ¼ x ½″ bar was reduced from ¼″ to .0085″ (Figure 1-a), in which operation the spread was 1/32″. Another bar ⅛ x ½″ was rolled with like diameter rolls in the conventional manner in one pass to .040″. The spreading here was 7/32″, (Figure 1-b). An interesting example is (Figure 1-c), which shows a 3/16 x 1″ bar, rolled in the conventional manner to .075″, which split exactly in the middle due to excessive spread.

The operation of the mill may best be described in the diagrammatic drawing of Figure 2, in which "A" is a crank drive which moves the housing "B" back and forth in Bed "C". The rolls "D" are held in alignment by Cage "E". The rolls are supported under the rolling load by the inclined and parallel surfaces of the housing and are held against those surfaces when no material is in the rolls by springs bearing against bearings on the trunnioned ends of the rolls. The air cylinder "F" manipulates the roll cage during part of the idle stroke (when no metal is between the rolls) and returns the rolls to their starting position at the end of each cycle. The hydraulic clamp "G" holds the blank "H" in a fixed position while the rolls engage the blank in the rolling operation. During the return stroke of the mill, the clamping pressure is released and the blank fed forward an increment of its length by the intermittently operated pinch rolls "J".

The illustration shows that part of the cycle in which the blank was fed forward and the clamping pressure

FIGURE 1—Sketches taken from actual rolled tests, (a) from Krause method (b and c) from conventional mills.



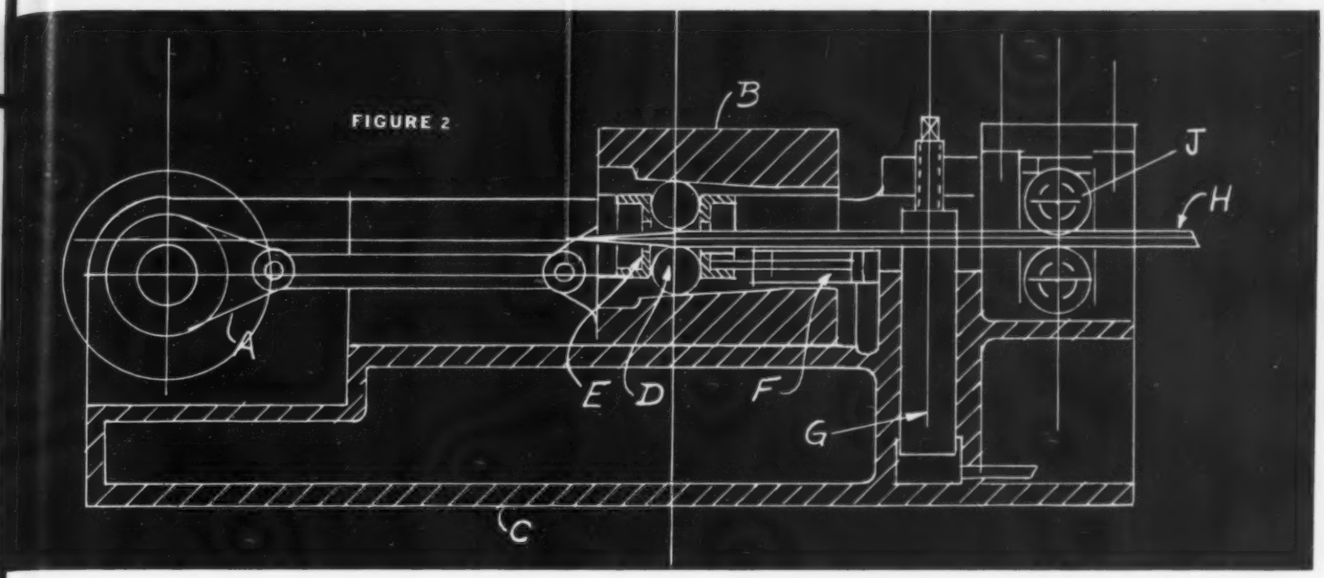


FIGURE 2—Diagram of Krause strip rolling mill, action of which is explained in the text.

is on in the cylinder holding the blank tightly between the end of the plunger and the adjusting screw. Air pressure is also on in the air cylinder "F" and holds the rolls in the starting position. As the crank "A" rotates counter clock-wise, the mill housing "B" advances and forces the rolls to descend towards the blank (which they clear near the end of the idle crank stroke). As the rolls come into contact with the blank, the increment of length which was fed forward is being rolled out to the finish gauge in this work stroke of the mill. On the return stroke of the crank, the mill housing and rolls are returned to the starting position while the clamp is released, the blank fed in and clamping pressure applied again, thereby completing the operating cycle.

Typical cases of measured power requirements per long ton in kw.-hrs. for various elongations, speeds and productions of finished strip per minute are given in Table I.

The principle of the rolling or reducing operation of the blank is shown in Figure 3. It should be noted that the contact arc of the rolls and the blank extends to both sides of the vertical center line of the rolls, therefore, the metal displaced in the sinking movement of the rolls on the left side of the vertical center line near "P" will flow to the left and the metal displaced

TABLE I.

PRODUCTION AND POWER DATA OF STRIP ROLLED ON THE KRAUSE EXPERIMENTAL ROLLING MILL

Cases	1	2	3	4	5
Stock Size Entering Mill	1/4 x 3"	3/16 x 8"	.134 x 12"	.170 x 8"	.178 x 4"
Strip Thickness Leaving Mill	.025"	.025"	.028"	.024"	.025"
Material	SAE-1015 Steel	SAE-1015 Steel	SAE-1015 Steel	17 Chrome Steel	18-8 Stainless
Elongation	10:1	7 1/2:1	4 3/4:1	7:1	7:1
Feed	3/16"	7/32"	7/32"	7/32"	5/32"
Rpm. of Crank Shaft	60	80	60	60	60
Peak Loads Amps. at 220 Volts	225	200	185	170	140
Mean Load Amps. (Approx. 1/3 Peak Amps.)	75	67	62	57	47
Mean Power—K.W.	16.5	14.7	13.6	12.5	10.3
Length of Strip Rolled per Stroke in Inches	1.9	1.6	1	1.5	1.1
Length of Strip Rolled per Minute in Feet	9.5	10.6	5	7.5	5.5
Weight of Strip Rolled per Hour Long Tons (2200 lbs.)	.057	.190	.155	.138	.050
Tons of Strip Rolled per K.W. Hr.	.0035	.013	.011	.011	.095

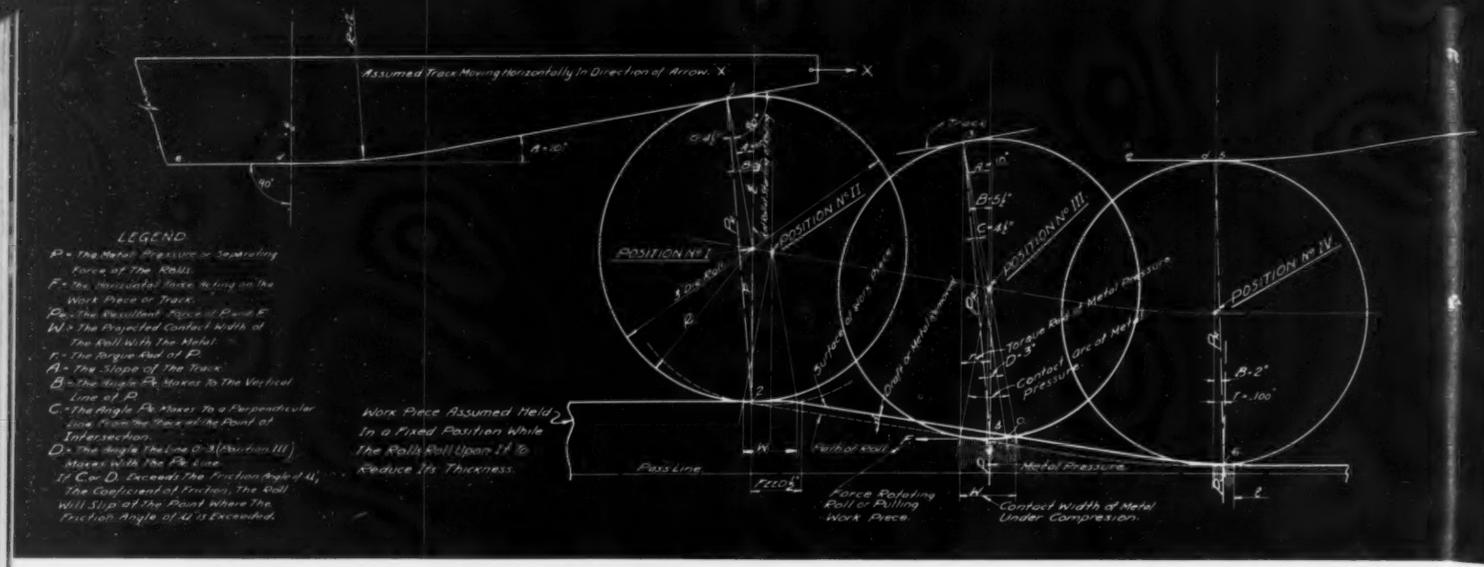

Assumed Track Moving Horizontally In Direction of Arrow X
LEGEND
P = The Metal Pressure or Separating Force of The Rolls.
F = The Horizontal Force Acting on the Work Piece or Track.
Pe = The Resultant Force of P and F.
W = The Projected Contact Width of The Roll With The Metal.
f = The Torque Rad of P.
A = The Slope of The Track.
B = The Angle Pe Makes To The Vertical Line of P.
C = The Angle Pe Makes To a Perpendicular Line From the Face at the Point of Intersection.
D = The Angle The Line C-3 (Position III) Makes With the Pe Line. If C or D Exceeds The Friction Angle of U, The Coefficient of Friction, The Roll Will Slip at the Point Where The Friction Angle of U is Exceeded.
Work Piece Assumed Held In a Fixed Position While The Rolls Roll Upon It To Reduce Its Thickness.
POSITION No I
POSITION No II
POSITION No III
POSITION No IV
Surface of Work Piece
Surface of Metal Rolled
Torque Rad of Metal Pressure
Contact Arc of Metal Pressure
Pass Line
Path of Roll
Metal Pressure
Force Rotating Roll or Pulling Work Piece
Contact Width of Metal Under Compression

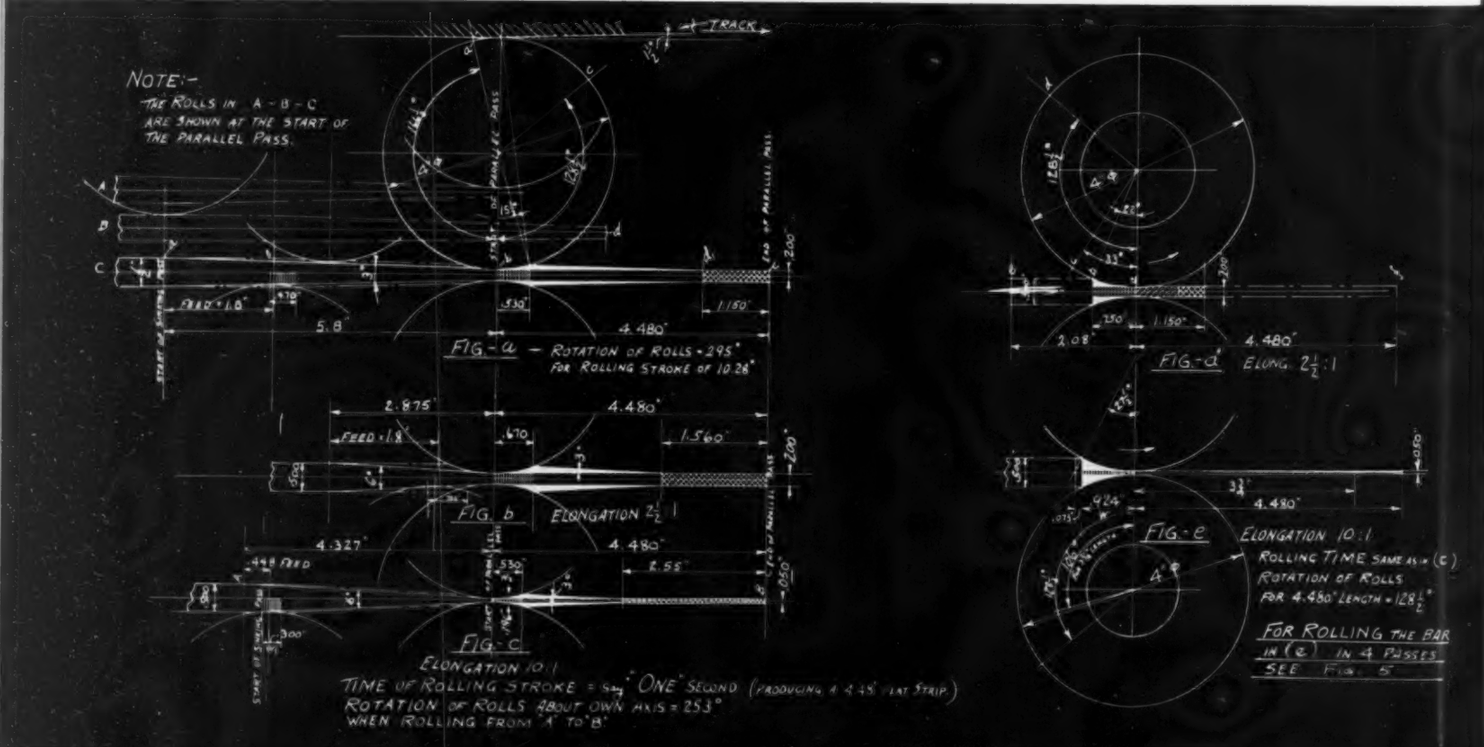
FIGURE 3—The principle of the reducing operation of the Krause strip mill, as here illustrated, is essentially a combined drawing and pressing operation.

to the right of "P" flows to the right ahead of the center-line of the rolls. Due to the force "F" applied to the bar, the metal displaced to the left of "P" is pulled away from the rolls. Also a good portion of the metal displaced to the right of "P" is drawn through the gorge of the pass. The rolls act as a die whose contact surface with the blank continually changes and rolls over the metal as it elongates, displacing it by pressing as in a press, and drawing as in a draw-bench with an anti-frictional die. It is due to this combined drawing and pressing action with the floating rolls of this process (which causes the metal to flow in a pass with diverging contact surfaces) that spreading of the metal is largely prevented.

By floating rolls, it is meant that the rolls are not restricted by mechanical means in their movement along the blank and, therefore, can follow the elongation of the blank as the metal is displaced. In fact, the rolls roll over the metal at a greater rate of travel than the bar elongates, thereby, eliminating the greatest part, if not all, of the force required to perform the friction work accompanying the process of rolling in the conventional rolling mills, wherein the metal is displaced backwards and must slide along the surface of the rolls as shown in Figure 4-d. This friction work is very great and results only in heat and wear of the rolls (like a wheel driven with set brakes) at an enormous expenditure of energy, which equals approximately 2Pf x length of the bar rolled, where P = the separating force of the rolls and "f", the coef. of friction.

The principle of elongating a blank with the floating rolls of the "Krause" process is illustrated in "B" of Figure 6. Assume a bar has been partially rolled and cut-off at the line "aa_1". If the rolling is then continued, the bar will be elongated to "a_2". The area of the metal displaced is shown by the shaded triangular sections ahead of the center line of the rolls and equals the cross-sectioned portion at the end of the bar. It is evident from this picture that the point "a_1" of the bar

FIGURE 4—Diagrammatic study of the rolling of metal blanks by the Krause method (a, b and c) and by the conventional method (d and e).


TRACK
NOTE:-
THE ROLLS IN A - B - C ARE SHOWN AT THE START OF THE PARALLEL PASS.
FIG. a — ROTATION OF ROLLS = 295° FOR ROLLING STROKE OF 10.28"
FIG. b ELONGATION 2½ : 1
FIG. c
ELONGATION 10 : 1
TIME OF ROLLING STROKE = say ONE SECOND (PRODUCING A 4.48" FLAT STRIP)
ROTATION OF ROLLS ABOUT OWN AXIS = 253°
WHEN ROLLING FROM 'A' TO 'B'
FIG. d ELONG. 2½ : 1
FIG. e
ELONGATION 10 : 1
ROLLING TIME SAME AS IN (c)
ROTATION OF ROLLS FOR 4.480" LENGTH = 128½°
FOR ROLLING THE BAR IN (c) IN 4 PASSES SEE FIG. 5

POWER REQUIRED TO ROLL THE BAR SHOWN IN "E" OF FIGURE 4 IN FOUR PASSES

Assumed Roll Speed = 4.480″ per Second

(The same as in "E" of Figure 4)

(A) Shows the division of a bar for reducing it in place of a single pass. Neglecting the spreading of the bar and the exit velocity of the bar above roll speeds, the conditions of rolling are as shown. The forces are calculated with the bar fully entered in the pass and the metal pressure is assumed at 100,000 lb. per sq. in. of projected contact area per inch width of bar.

$$\text{Work in ft. lb.} = 2P \frac{r}{R} \times \frac{l}{12}$$

$$W = 2 \times \text{metal pressure} \times \frac{\text{torque rad.}}{\text{roll rad.}} \times \frac{\text{rolled length in inches}}{12}$$

$$W_1 = 62{,}800 \times .314 \times .752 \times \frac{2}{2} = 14{,}810 \text{ in. lb.}$$

$$W_2 = 51{,}800 \times .259 \times 1.418 = 19{,}024 \text{ in. lb.}$$

$$W_3 = 39{,}800 \times .199 \times 2.872 = 22{,}804 \text{ in. lb.}$$

$$W_4 = 24{,}000 \times .120 \times 4.480 = 12{,}902 \text{ in. lb.}$$

Total Work = 69,540 in. lb. = 5,795 ft. lb.

Total rotation of rolls for lengths rolled = 273 degrees

$$\text{(Length of contact surface} = 4 \times \pi \times \frac{273}{360} = 9.52'')$$

$$\text{Ratio} \frac{\text{Rolled lengths}}{\text{Finished lengths}} = \frac{9.52}{4.48} = 2.12$$

The finished length of the bar produced = 4.48″ which is less than ½ the length the rolls had actually covered under rolling pressures.

$$\text{Time of rolling} = \frac{9.52}{4.48} = 2.12 \text{ seconds at given speed in four passes.}$$

Therefore: $2.12 \times 5{,}795 = 12{,}285$ ft. lb.

$$\text{Total work required, which is } \frac{12{,}285}{4{,}400} = 2.8 \text{ times more than required for "c" in Figure 4.}$$

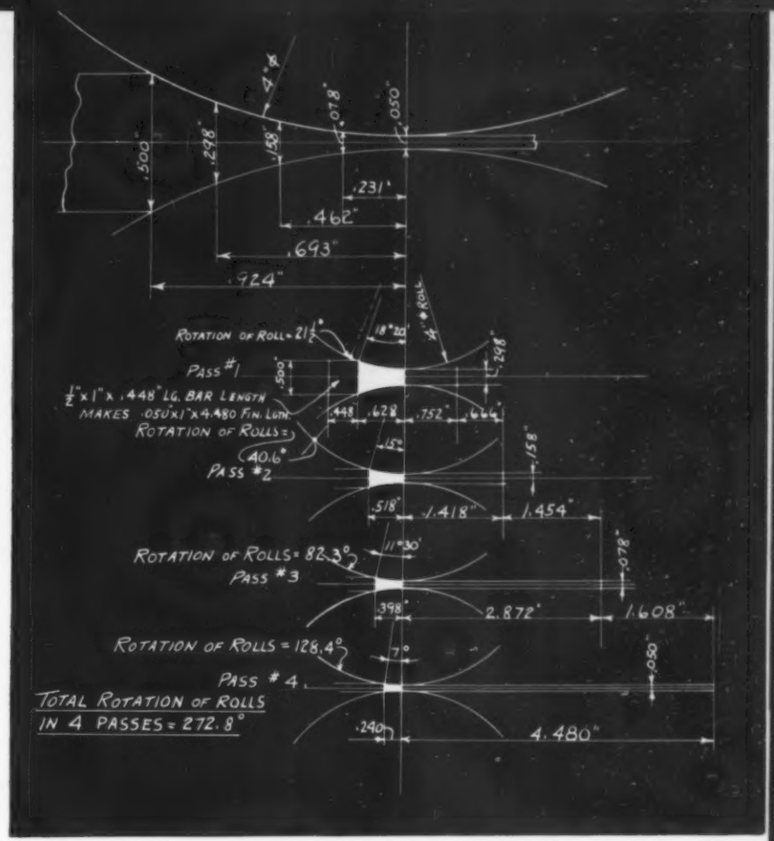


FIGURE 5—Diagram showing reduction of .5″ bar to .05″ thickness in four passes of a conventional mill.

will reach the point "a_2" at the same time the center of the roll "o_1" reaches the point "o_2". As the distance "o_1" to "o_2" is greater than the distance from "a_1" to "a_2" it follows that the point "o_1" overtakes the point "a_1" at the line "o_2a_2" where the elongation is completed. It has been experimentally proven that the metal in contact with the rolls at "a_1" does not move relative to the surface of the rolls in going through the pass and, therefore, is the "No-Slip" point on the rolls. Also, as the metal in contact with the rolls elongates in the direction of arrow "x", it carries (floats) the rolls along with it while they rotate in advancing from "o_1" to "o_2". The rotation of the rolls in this case is only through the angle "A", whereas in mills in which the roll travel is governed by rack and pinion drives (Neuberth, Schuster & Coe) or where the rolls rotate in fixed position (Steckel, Coryell and the conventional mills), the point "a_1" of the bar would slide on the surface of the rolls from "a_1" to "b" causing the rolls to rotate through the angle "B".

In Figure 4, there are shown in Figures "a", "b" and "c" diagrams illustrating the "Krause" method of elongating metal blanks. Compared with these are Figures "d" and "e" showing the method in the conventional rolling mills.

In Figure 4-a is shown the development of the work

POWER REQUIRED FOR THE DISPLACEMENT OF METAL AS PER FIGURES "C" AND "E"

Work for Rolling the Section as in "C" of Figure 4

WORK FOR ROLLING THE WEDGE

W_1 Contact width at start of rolling = .300″

W_2 Contact width at end of wedge = .530″

$$\text{Average contact width} = \frac{.300 + .530}{2} = .415''$$

P_1 Average metal pressure at 100,000 lb. per sq. inch proj. contact area = .415 x 100,000 = 41,500 lb. per inch width of strip.

$$F_1 \text{ Average pulling force acting on each track} = \frac{41500 \times .208}{4} = 2{,}160 \text{ lb.}$$

d_1 Distance through which F_1 acts = 2 x 4.327 = 8.654″

$$\text{Work } F_1 \times d_1 = \frac{2160 \times 8.654}{12} = 1558 \text{ ft. lb.}$$

WORK FOR ROLLING THE FLAT

W_2 At start of parallel pass = .530″

W At end of parallel pass = 0

$$\text{Average contact width} = \frac{.530}{2} = .265''$$

P_2 Average metal pressure at 100,000 lb. per sq. ft. Projected contact area = 26,500 lb. per inch width of strip

$$F_2 \text{ Average pulling force on each track} = \frac{26{,}500 \times .13}{4} = 860 \text{ lb.}$$

d_2 Distance through which F_2 acts = 2 x 4.48 = 8.96″

$$\text{Work } F_2 \times d_2 = \frac{860 \times 8.96}{12} = 642 \text{ ft. lb.}$$

Total work to roll a ½″ bar to .050 x 1 x 4.80″ = 2 (1558 + 642) = 4400 ft. lb.

Work for Rolling the Section as in "E" of Figure 4

Contact width "W" = .924″

Metal pressure at 100,000 lb. per sq. in. of projected contact area = 92,400 lb

Force to rotate each roll applied to pull the bar = F

$$F = \frac{92400 \times .462}{2} = 21{,}200 \text{ lb.}$$

d Distance through which "F" acts = 4.48″

$$\text{Work } Fd = \frac{21{,}200 \times 4.48}{12} = 7915 \text{ ft. lb. per roll}$$

And 15,830 ft. lb. total for 2 rolls.

Difference in ft. lb. of work in the two methods as applied in "c" and "e" = 11,430 ft. lb.

$$\text{Therefore: If the time of rolling is the same in each case, } \frac{15830}{4400} = 3.6 \text{ times}$$

more power is required in "e" then in "c".

NOTE: Spreading and the exit velocity of the bar above roll surface speeds has been neglected here.

stroke rolling operation in the "Krause" process when a ½" bar is reduced to .200" (Elong. 2½:1) with a feed of 1.8" in a mill having a 1½ degree inclined track surface. The finished (flat) length of bar produced with each work stroke = Feed x Elong. = 1.8 x 2.5 = 4.48".

To make clear the procedure of this operation, assume the bar rolled out at "C" of Figure 4-a is cut off at "b", and the rolls returned to the starting position at "a", as shown in light lines at "A". Now if the bar is fed forward as shown in light lines at "B", the rolling operation can take place as shown at "C". As the rolls advance from "a" to "b", the sinking movement is completed and the parallel movement of the rolls begins. The elongation produced in the sinking movement of the rolls is indicated by the shifting of the end of the bar from "d" to "d_1". Completing the work stroke, the rolls advance in a parallel pass from "b" to "c". During this movement of the rolls, the bar is elongated from "d_1" to "c", and a flat section 4.48" in length is produced. The shaded triangular area between "b" and "d_1" equals the area .200 x 1.150" shown in the criss-cross sectioned end of the bar and represents the elongation of the bar in the parallel pass of the mill. It is evident that any volume fed forward at the start of the work stroke is rolled out to a finished section equal in volume. "What goes in must come out", and therefore, the metal to be transformed in the parallel pass is ahead of the vertical center line of the rolls and must equal the volume of the metal fed into the mill.

The energy required to roll the 4.48" length of bar in Figure 4-a equals approximately 4130 Ft. Lbs. which can be computed roughly as follows:

Assume the bar is one inch wide and the compression stress "S_c" for the material of the bar = 100,000 lbs. per square inch of the projected contact area.

Then if W = The projected contact width of the rolls with the bar

F = The tangential force acting on the bar to rotate the rolls and

E = The energy in ft. lbs. to roll the 4.48" length of bar.

Then:

(a) To move the rolls through the sinking pass:

1. Movement of the rolls from "a" to "e".

$$W\ (avg.) = \frac{.470}{2} = .235".$$

$$F\ (avg.) = 2 \times 100{,}000 \times .235 \times \frac{.7 \times .235}{4} = 1930 \text{ lbs.}$$

$$E_1\ (avg.) = \frac{2 \times 1.8}{12} \times 1930 = 580 \text{ ft. lbs.}$$

2. To move the rolls from "e" to "b".

$$W\ (avg.) = \frac{.470 + .530}{2} = .500".$$

$$F\ (avg.) = 2 \times 100{,}000 \times .500 \times \frac{.7 \times .5}{4} = 8750 \text{ lbs.}$$

$$E_2\ (avg.) = \frac{2 \times 4}{12} \times 8750 = 5840 \text{ ft. lbs.}$$

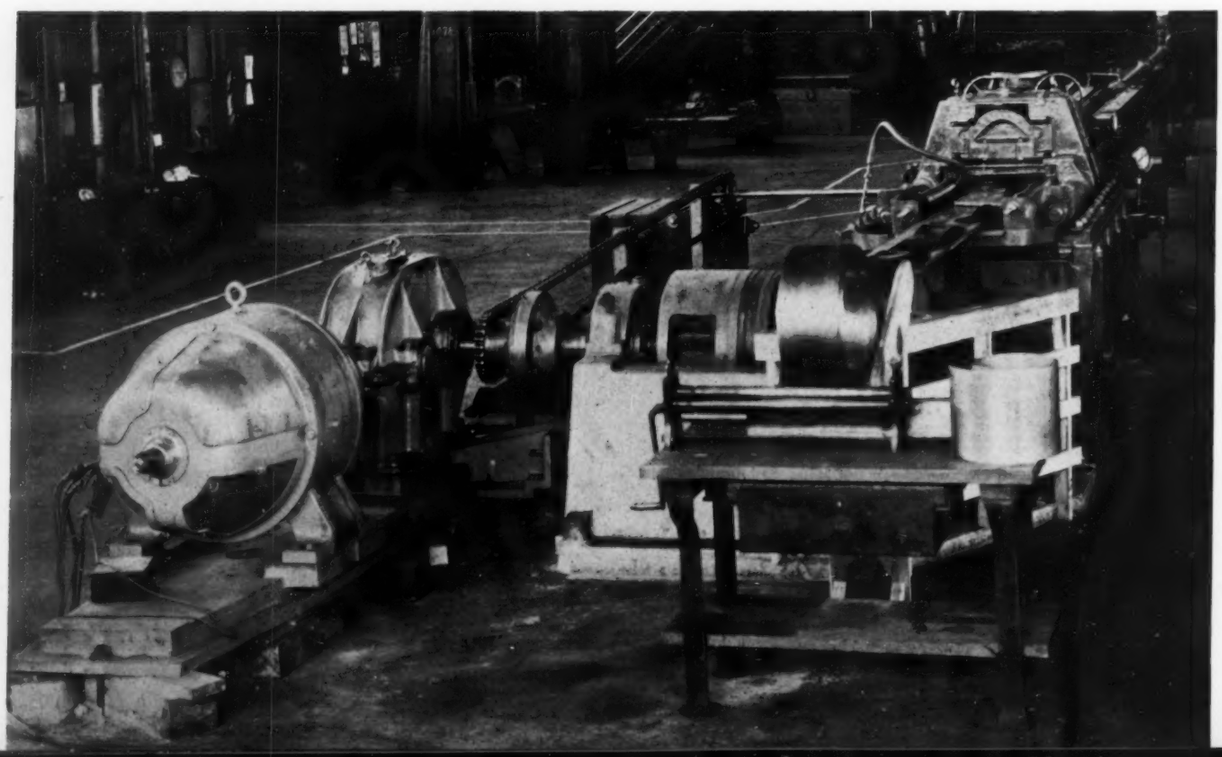
(b) To move the rolls through the parallel pass:

$$W\ (avg.) = \frac{.530}{2} = .265".$$

$$F\ (avg.) = 2 \times 100{,}000 \times .265 \times \frac{.7 \times .265}{4} = 2460 \text{ lbs.}$$

$$E_3\ (avg.) = \frac{2 \times 4.48}{12} \times 2460 = 1840 \text{ ft. lbs.}$$

General view of Krause mill from the discharge end. At the left is the crank shaft drive, a 75 h-p. motor. At upper right is the mill housing, beyond which can be seen the feed cylinder and entry table.



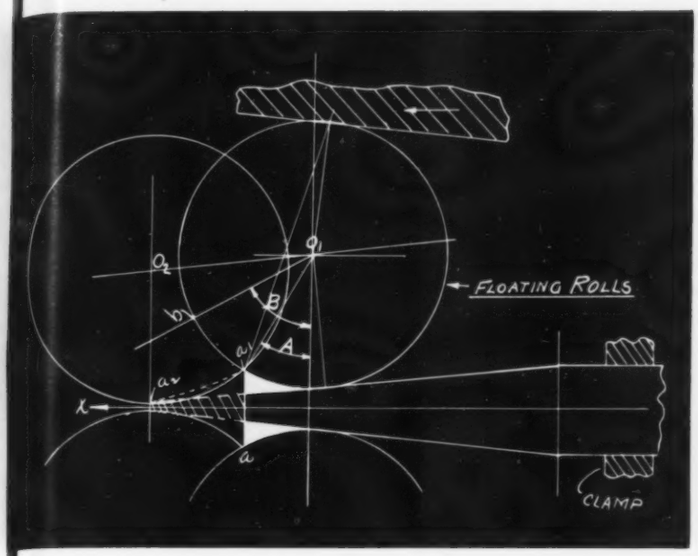


FIGURE 6—In the Krause process of rolling, the point a, of the bar does not shift on the surface of the rolls in its movement from O_1 to O_2. In mills with fixed driven or idle rolls, the point a, of the bar slides on the surface of the roll to point b.

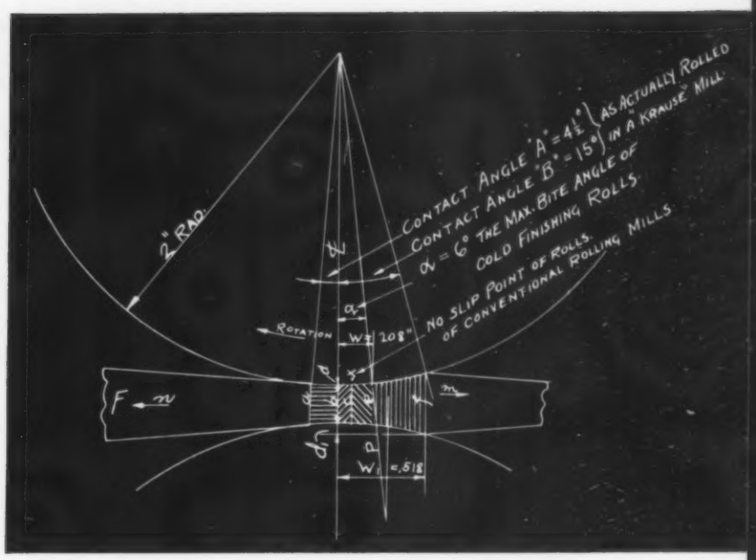

CONTACT ANGLE "A" = 4½° (AS ACTUALLY ROLLED
CONTACT ANGLE "B" = 15°) IN A KRAUSE MILL
α = 6° THE MAX. BITE ANGLE OF
COLD FINISHING ROLLS.
NO SLIP POINT OF ROLLS.
OF CONVENTIONAL ROLLING MILLS
2" RAD.
ROTATION
W = .208"
W = .518"

FIGURE 7—The principle of metal displacement in the Krause mill is here illustrated. From a to c and beyond c toward e, the metal is drawn through the rolls as in a die. From e to f the metal is displaced in direction of arrow m under tension and compression.

Total energy required to move the rolls from "a" to "c" equals $E_1 + E_2 + E_3 = 580 + 5840 + 1840 =$ 8260 ft. lbs.

To roll an equal length and section of a bar by the conventional rolling mill method shown in Figure 4-d, the energy required under like conditions of stress will be as follows:

W = .750".

$$F = 2 \times 100{,}000 \times .750 \times \frac{.7 \times .75}{2} = 39{,}000 \text{ lbs.}$$

$$E = 39{,}000 \times \frac{4.48}{12} = 14{,}500 \text{ ft. lbs.}$$

If the 4.48" length of the bar is rolled in the same time in each case then the power consumed (kw.-sec) in the latter case is 1.75 times greater than in the first case.

Still greater power differences arise between case "c" and "e" as shown in the calculations in Figure 4. Of course, case "e" is too much exaggerated and does not represent practical conditions. It serves only as an illustration what a 10:1 elongation would look like if it could be performed in a single pass. More practical comparisons can be gained from Figure 5 where the same bar is shown rolled in 4 passes. The energy required in this case is 2.8 times greater than the energy required for rolling the bar in Figure 4-c.

As a check against the torque method employed in the foregoing calculations of the work, let us now compute it from the Fink formula, $W = S \times V \times \text{Log}_e n$.

(1) Figure 4-d.

$$n = \text{The elongation} = \frac{.500}{.200} = 2.5.$$

Log_e of 2.5 = .916.

V = Volume = .200 x 1 x 4.48 = .896 cu. in. (Say .900 cu. in.)

S = Stress coefficient assumed at 200,000 lb. per sq. in.

$$\text{Then Work}_d \text{ (ft. lbs.)} = \frac{200{,}000 \times .9 \times .916}{12} = 13{,}740 \text{ ft. lbs.}$$

(2) Figure 4-a.

$$n = \frac{\text{Final length}}{\text{Initial length}} = \frac{10.28}{5.8} = 1.76.$$

Log_e of 1.76 = .565.

V = .500 x 1 x 1.8 = .900 cu. inches.

If S is the same as in Case "d" (which it is not on account of the different elongation, for which no data is available)

$$\text{Then } W_a = \frac{200{,}000 \times .9 \times .565}{12} = 8470 \text{ ft. lbs.}$$

$$\text{Ratio of } \frac{\text{Work}_d}{\text{Work}_a} = \frac{13740}{8470} = 1.62.$$

$$\text{The ratio of } \frac{\text{Work}_d}{\text{Work}_a} \text{ from torque method} = \frac{14500}{8260} = 1.75.$$

Investigating Cases "c" and "e" of Figure 4 the same way, we get:

(3) Figure 4-e.

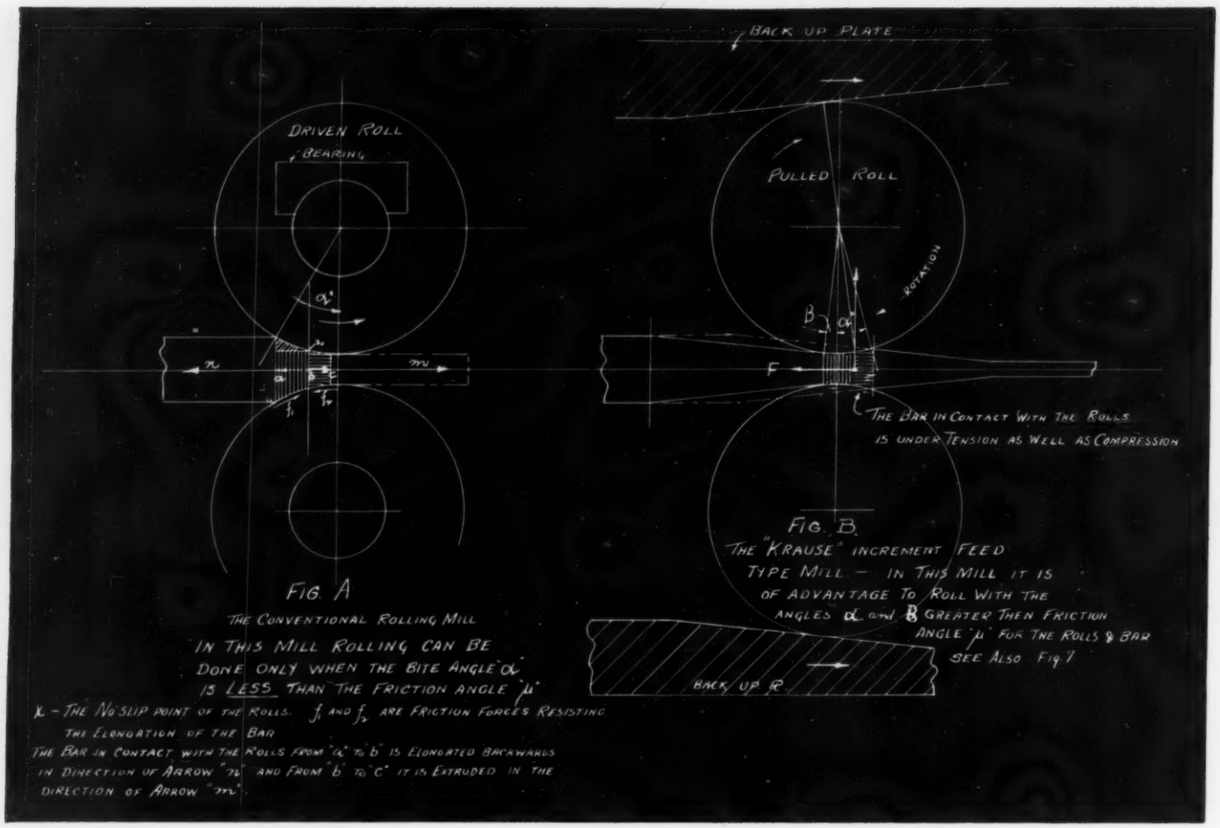
$$n = \frac{.500}{.050} = 10$$

Log_e of 10 = 2.30.

V = 4.48 x 1 x .050 = .224 cu. inches.

S = Say 350,000 lbs. per sq. in.

$$\text{Then } W_e = \frac{350000 \times .224 \times 2.3}{12} = 15{,}020 \text{ ft. lbs.}$$


BACK UP PLATE
DRIVEN ROLL
BEARING
PULLED ROLL
ROTATION
THE BAR IN CONTACT WITH THE ROLLS IS UNDER TENSION AS WELL AS COMPRESSION
FIG. A
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IN THIS MILL ROLLING CAN BE DONE ONLY WHEN THE BITE ANGLE α IS LESS THAN THE FRICTION ANGLE μ
N - THE NO SLIP POINT OF THE ROLLS. f1 AND f2 ARE FRICTION FORCES RESISTING THE ELONGATION OF THE BAR
THE BAR IN CONTACT WITH THE ROLLS FROM "a" TO "b" IS ELONGATED BACKWARDS IN DIRECTION OF ARROW "n" AND FROM "b" TO "c" IT IS EXTRUDED IN THE DIRECTION OF ARROW "m".
FIG. B.
THE "KRAUSE" INCREMENT FEED TYPE MILL — IN THIS MILL IT IS OF ADVANTAGE TO ROLL WITH THE ANGLES α and β GREATER THEN FRICTION ANGLE μ FOR THE ROLLS & BAR
SEE ALSO Fig 7
BACK UP R

FIGURE 8—Comparative diagrams of metal flow, Krause mill vs. conventional mill.

(4) For Figure 4-c.

$$n = \frac{\text{Final length}}{\text{Initial length}} = \frac{8.807}{4.237} = 2.08.$$

Log_e of 2.08 = .732.

V = .500 x 1 x .448 = .224 cu. inches.

S = Say 350,000 lbs. per sq. in. as in Case "e".

$$\text{Then } W_e = \frac{350{,}000 \times .224 \times .732}{12} = 4770 \text{ ft. lbs.}$$

$$\text{Ratio } \frac{W_e}{W_c} = \frac{15020}{4770} = 3.2$$

$$\text{Ratio } \frac{W_e}{W_c} \text{ from Torque method (Fig. 4)} = \frac{15830}{4400} = 3.6.$$

Thus it is seen that the relative work or power requirements as calculated by the two methods check pretty well.

Another indication of the power saving accomplished with the Krause process is seen by comparing the tons of strip rolled per kw.-hr. in Table I with the following calculations of the tons of strip rolled per kw.-hr. in the 4-high mill of Table II.

Here .245 x 29⅜" wide strip is rolled to .025" in 5 passes. The length of the reduced strip is 980 feet. The time of rolling is at the full rolling speed of each pass is 5.4 minutes. Assuming 1.6 minutes are lost in the starting and stopping operations of the mill for the 5 passes, then the 980 ft. of strip are rolled in 7 minutes.

$$\text{Length rolled per min.} = \frac{980}{7} = 140 \text{ ft.}$$

$$\text{Length rolled per hr.} = 140 \times 60 = 8400 \text{ ft.}$$

$$\text{Wt. of strip rolled} = \frac{8400 \times 2.4}{2200} = 9.4 \text{ Tons.}$$

Power consumed in the 5 passes = 7730 kw.

$$\text{Tons of strip rolled per kw.-hr.} = \frac{9.4}{7730 \text{ kw.}} = .0012 \text{ tons}$$

In Table I is shown a ¼ x 3" bar rolled to .025" in a Krause mill for which the tons of strip rolled per kw.-hr. = .0035 Tons. This is 3 times more steel per kw.-hr. than in the 4-high mill given above.

The reason for the great savings of power in the "Krause" mill, no doubt, lies in the substantial elimination of the friction work accompanying the process of elongation in the conventional rolling mills. This friction work is indicated in Figure 4-d by the sliding of the point "b" to "d" under the load of the metal pressure and equals approximately 2Pf x length of the arc "bd" for every 106 degrees rotation of the rolls, where P = the separating force of the rolls and "f", the coef. of friction. It is also to be noted that the

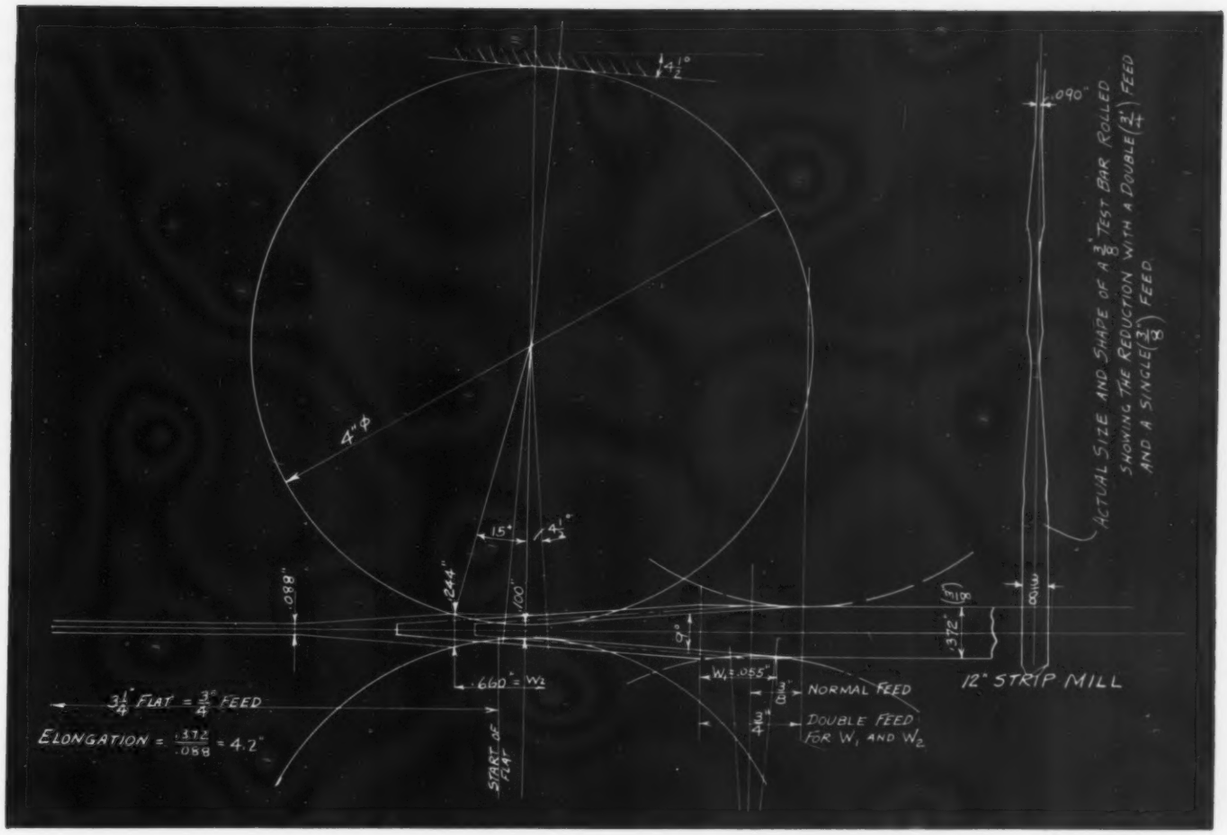

FIGURE 9—Diagrammatic study of rolling by the Krause method, as measured from actual test bar.

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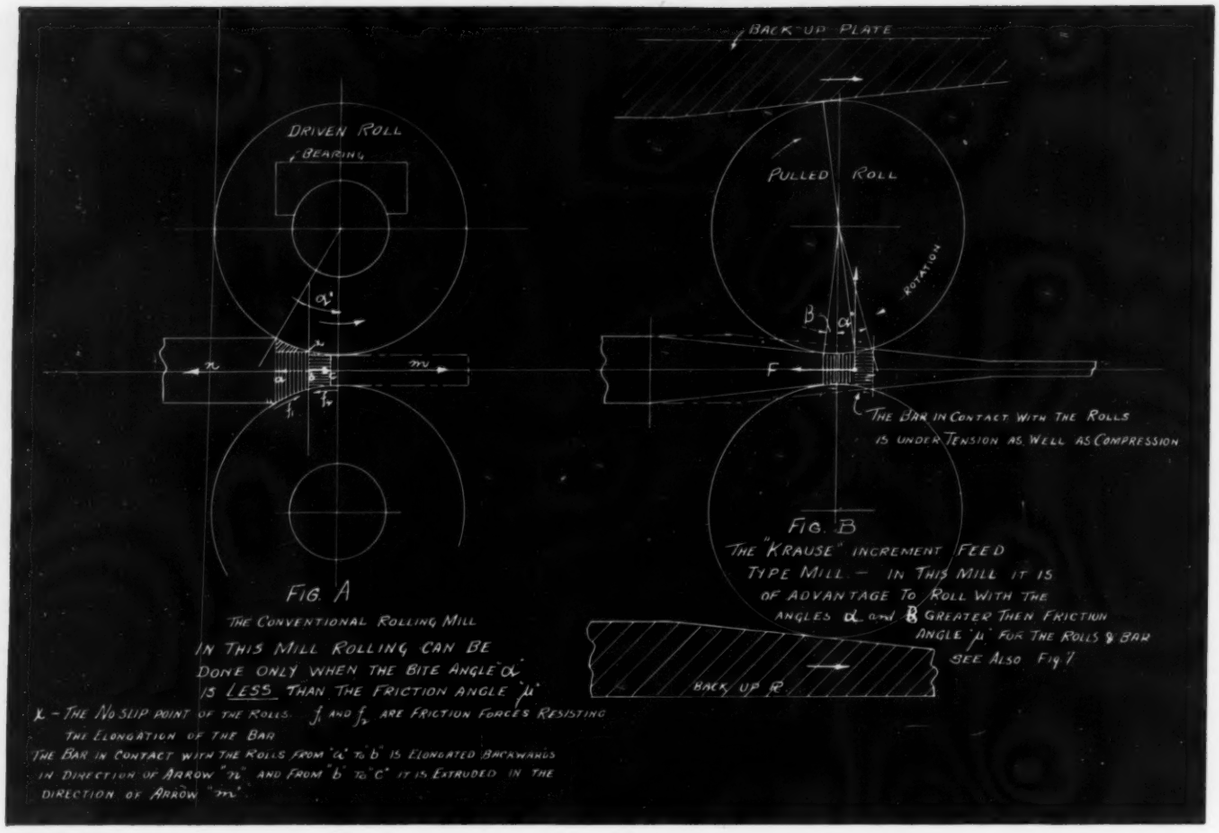
FIGURE 10—Diagrammatic presentation of rolling data from three actual four-high cold mills.

bar in this case is drawn into a pass with converging surfaces wherein the metal is drawn in by the rolls and displaced with a tendency to expel it against the converging surfaces of the pass. In other words, as the surface speed of the rolls is greater than the surface speed of the bar in contact with them (except at the exit end of the pass) and the pass is convergent in the

STECKEL MILL DATA.
ROLLING STAINLESS STL. STRIP FROM .045" TO .020"
16" WIDE AT A ROLL SPEED OF 600 FT/MIN. IN 6 PASSES.
COST OF MILL WITH ELECTRICAL EQUIPMENT, ABOUT $450,000.
REDUCTIONS PER PASS ARE ADJUSTED
TOTAL ROLLING TIME AT 600'/min = 2.87 MIN.
PRODUCTION TIME = 2.87/0.66 = 4.3 MIN. (assuming 2/3 of the production time is consumed in changing from coil to coil and in starting and stopping between reverses of direction).
LENGTH OF STRIP PRODUCED PER MIN. = 475/4.3 = 110 FT/MIN.
TOTAL ELONGATION = 4.75 : 1
A
L = LENGTH OF STRIP IN FEET
T = TIME IN PASS, MINUTES
t = THICKNESS OF STRIP
R = REDUCTION IN PASS, %
4-HI STRIP MILL DATA.
6½ x 20 x 18" REVERSING COLD STRIP MILL
WITH DRIVEN WORK ROLLS AND TENSION REELS
ROLLING LOW CARBON STEEL STRIP FROM .109" TO .009" x 12" WIDE
IN 5 PASSES — ROLL SPEED = 600'/min. (183m/min)
MILL MOTOR 300 HP. - REEL MOTORS, 35 HP EACH.
COST OF MILL $42000, ELECTRICAL EQUIPMENT $43000
TOTAL ROLLING TIME = 5.7 MIN.
PRODUCTION TIME = 5.7/0.66 = 8.6 MIN.
LENGTH OF STRIP ROLLED PER MIN. = 140 FT/MIN.
TOTAL ELONGATION = 12:1
B
4-HI COLD STRIP MILL
16" x 48" x 49" REVERSING MILL - DRIVEN WORK ROLLS & REELS
ROLLING LOW CARBON STRIP STL. FROM .072" TO .010"
IN 4 TO 5 PASSES. - ROLL SPEED = 800'/min. (1000'/min)
TOTAL ROLLING TIME = 2.52 MIN.
PRODUCTION TIME = 2.52/0.66 = 3.8 MIN.
LENGTH OF STRIP ROLLED PER MIN. IN 4 PASSES = 190'/min.
TOTAL ELONGATION = 7.2 : 1
IF ROLLING THE SAME STRIP IN 5 PASSES
LENGTH OF STRIP PRODUCED PER MIN. = 145'/min.
C
SEE ALSO P. 19


BACK-UP PLATE
DRIVEN ROLL
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SEE ALSO FIG 7
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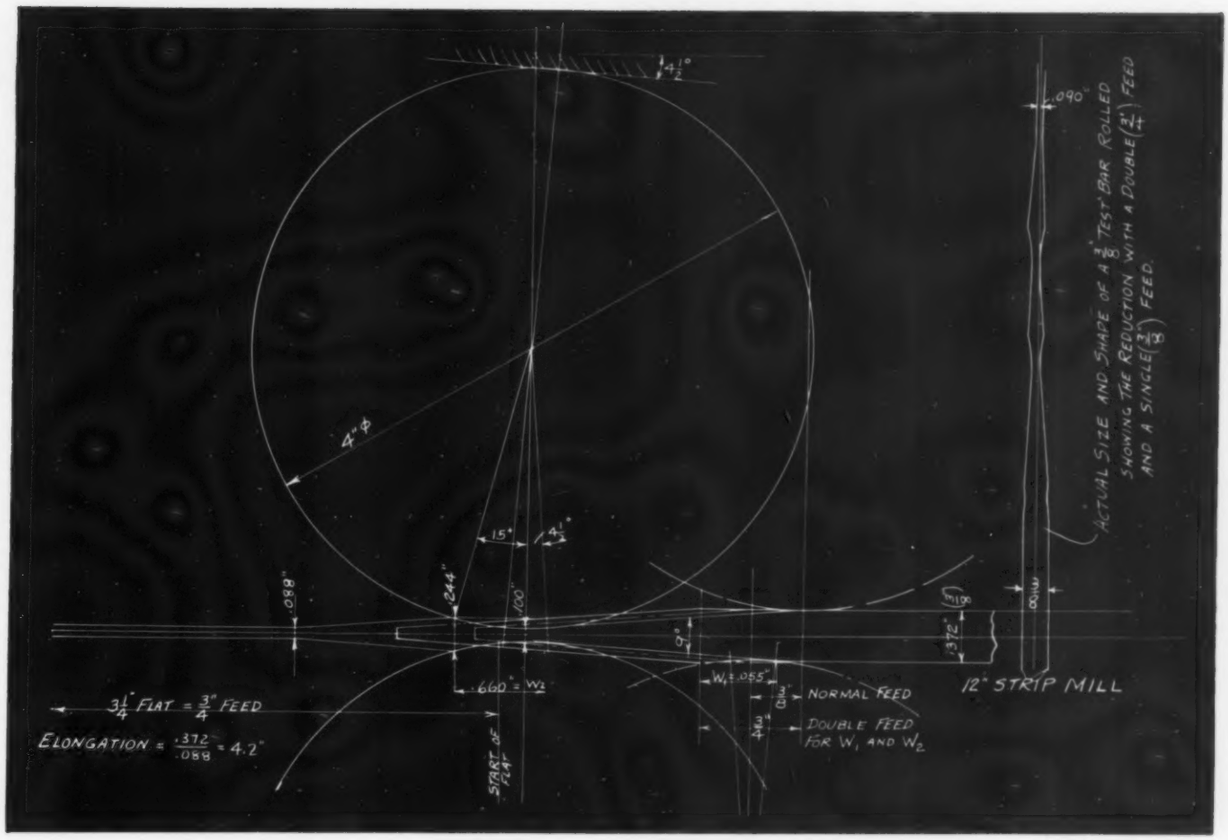

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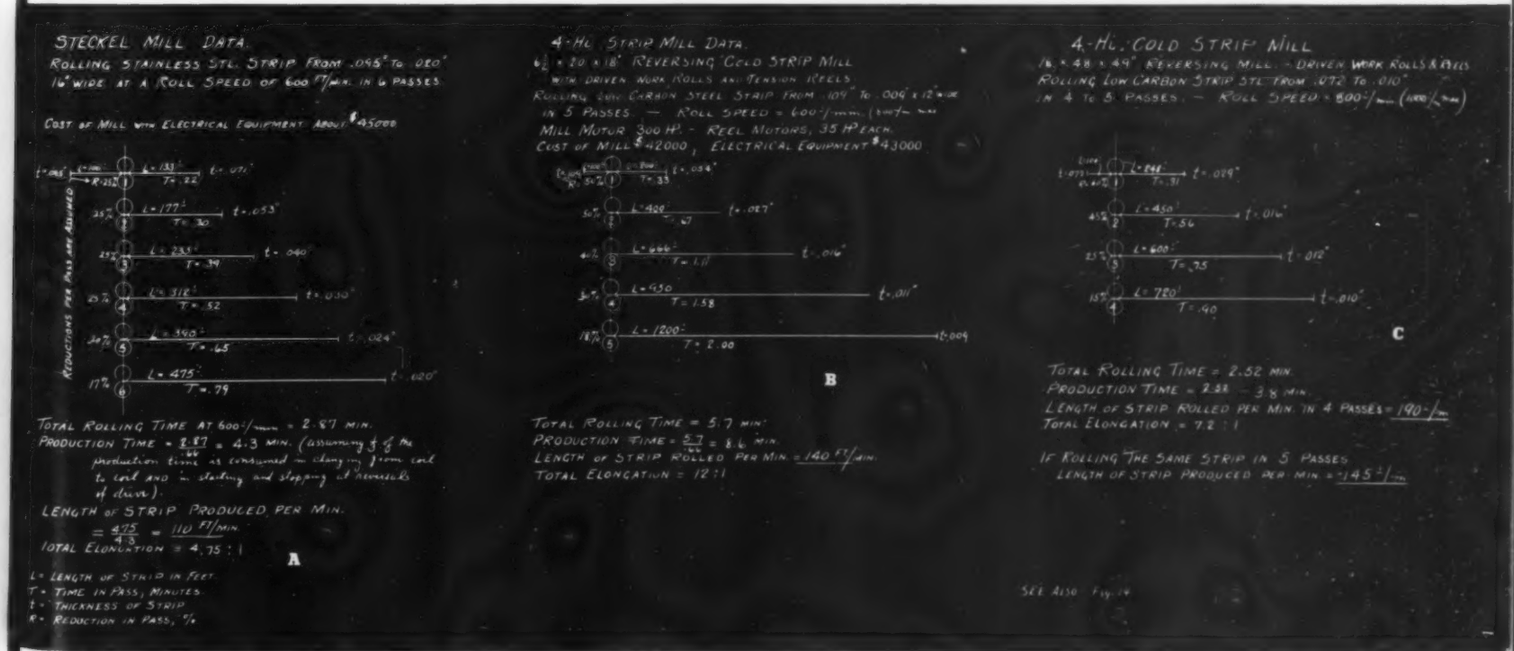
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TOTAL ROLLING TIME AT 600'/min = 2.87 MIN.
PRODUCTION TIME = 2.87/66 = 4.3 MIN. (assuming 1/3 of the production time is consumed in changing from coil to coil and in starting and stopping at intervals of days).
LENGTH OF STRIP PRODUCED PER MIN. = 475/4.3 = 110 FT/MIN.
TOTAL ELONGATION = 4.75 : 1
A
L = LENGTH OF STRIP IN FEET.
T = TIME IN PASS, MINUTES
t = THICKNESS OF STRIP
R = REDUCTION IN PASS, %
4-HI. STRIP MILL DATA.
20" x 18" REVERSING COLD STRIP MILL WITH DRIVEN WORK ROLLS AND TENSION REELS.
ROLLING LOW CARBON STEEL STRIP FROM .109" TO .006" x 12" WIDE IN 5 PASSES. — ROLL SPEED = 600'/min. (1000'/min)
MILL MOTOR 300 HP. - REEL MOTORS, 35 HP EACH.
COST OF MILL $42000, ELECTRICAL EQUIPMENT $43000
TOTAL ROLLING TIME = 5.7 MIN.
PRODUCTION TIME = 5.7/66 = 8.6 MIN.
LENGTH OF STRIP ROLLED PER MIN. = 140 FT/MIN.
TOTAL ELONGATION = 12:1
B
4-HI. COLD STRIP MILL
16" x 48" x 49" REVERSING MILL. - DRIVEN WORK ROLLS & REELS
ROLLING LOW CARBON STRIP STL. FROM .072 TO .010" IN 4 TO 5 PASSES. — ROLL SPEED = 800'/min (1000'/min)
TOTAL ROLLING TIME = 2.52 MIN.
PRODUCTION TIME = 2.52/66 = 3.8 MIN.
LENGTH OF STRIP ROLLED PER MIN. IN 4 PASSES = 190'/m
TOTAL ELONGATION = 7.2 : 1
IF ROLLING THE SAME STRIP IN 5 PASSES LENGTH OF STRIP PRODUCED PER MIN. = 145'/m
C
SEE ALSO Fig. 14

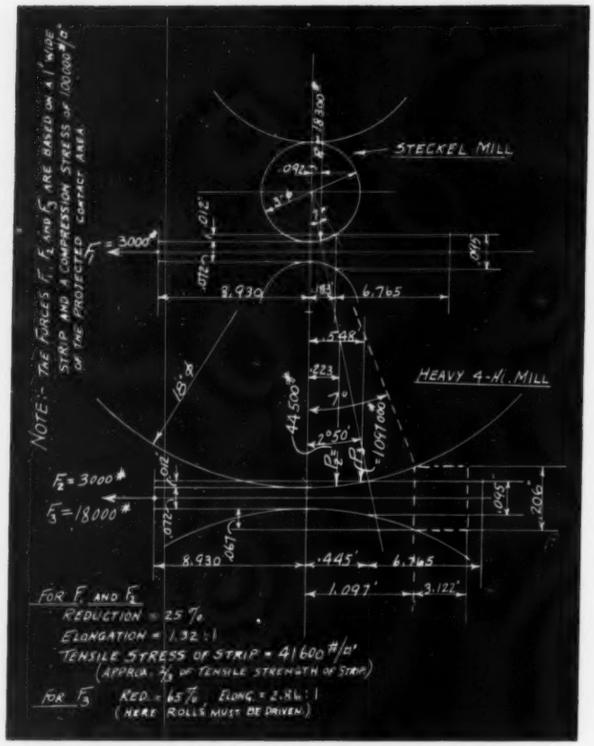
NOTE:- THE FORCES F1, F2 AND F3 ARE BASED ON A 1" WIDE STRIP AND A COMPRESSION STRESS OF 100,000 #/□"
OF THE PROJECTED CONTACT AREA
STECKEL MILL
HEAVY 4-H. MILL
F1 = 3000#
F2 = 3000#
F3 = 18000#
8.930
6.765
.548
44,500#
8.930
.445
6.765
1.097
3.122
FOR F1 AND F2
REDUCTION = 25 %
ELONGATION = 1.32 : 1
TENSILE STRESS OF STRIP = 41600 #/□"
(APPROX. 2/3 OF TENSILE STRENGTH OF STRIP)
FOR F3 RED. = 65 %; ELONG. = 2.86 : 1
(HERE ROLLS MUST BE DRIVEN)

FIGURE 11—Comparison of rolling on Steckel mill and on a heavy four-high mill.

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FIGURE 12—(A) Conditions arising in Krause mill when rolling same strip as in Figure 11. (B) Two strips may be rolled simultaneously with a flat bar as a mandrel between them in the Krause mill.

direction of rolling, the tendency of the rolls is to draw a greater volume of metal into the pass than can flow out of it. The result is a crowding of the metal in the pass and slippage of the rolls on the bar accompanied by spreading and an increase of the flow stress of the metal. Now in the operation of the rolls in "a" of Figure 4 the metal is displaced principally ahead of the vertical center-line of the rolls in a pass with diverging surfaces in the direction of rolling in which the metal can flow away quite freely. Therefore, the metal is displaced in a natural way—the line of least resistance. Within this pass, the metal is displaced in a progressively increasing volume as the space in the pass increases also.

Another point in favor of displacing the metal as in "a", Figure 4, (the Krause process) is that the contact angle of the rolls with the blank can be many times greater than the friction angle for the material of the blank and rolls, thereby reducing the flow resistance of the metal. Whereas, in the conventional mills with driven rolls, the contact width *must* be within said friction angle so that the bar may enter the pass. In the first case, the draft *is not* limited by the coefficient of friction for the rolls and the bar, but in the latter case, the draft is definitely limited by the coefficient of friction for rolls and bar.—See Figures 7 and 8.

Figure 7 shows the principle of the metal displacement in the "Krause" mill. In the conventional rolling mill process, the no-slip point of the metal in contact with the rolls is ahead of the middle of the contact angle "a", say at "x", therefore, relative to the surface of the rolls, the metal in the pass between the lines "b" and "c" flows forward and is extruded in the direction of rolling, whereas, the metal between the lines "c" and "e" flows backwards thereto. The metal within this zone (b to e) is resisted in its flow by the friction between the bar and rolls which results in an increase of the unit compression or flow stress of the material

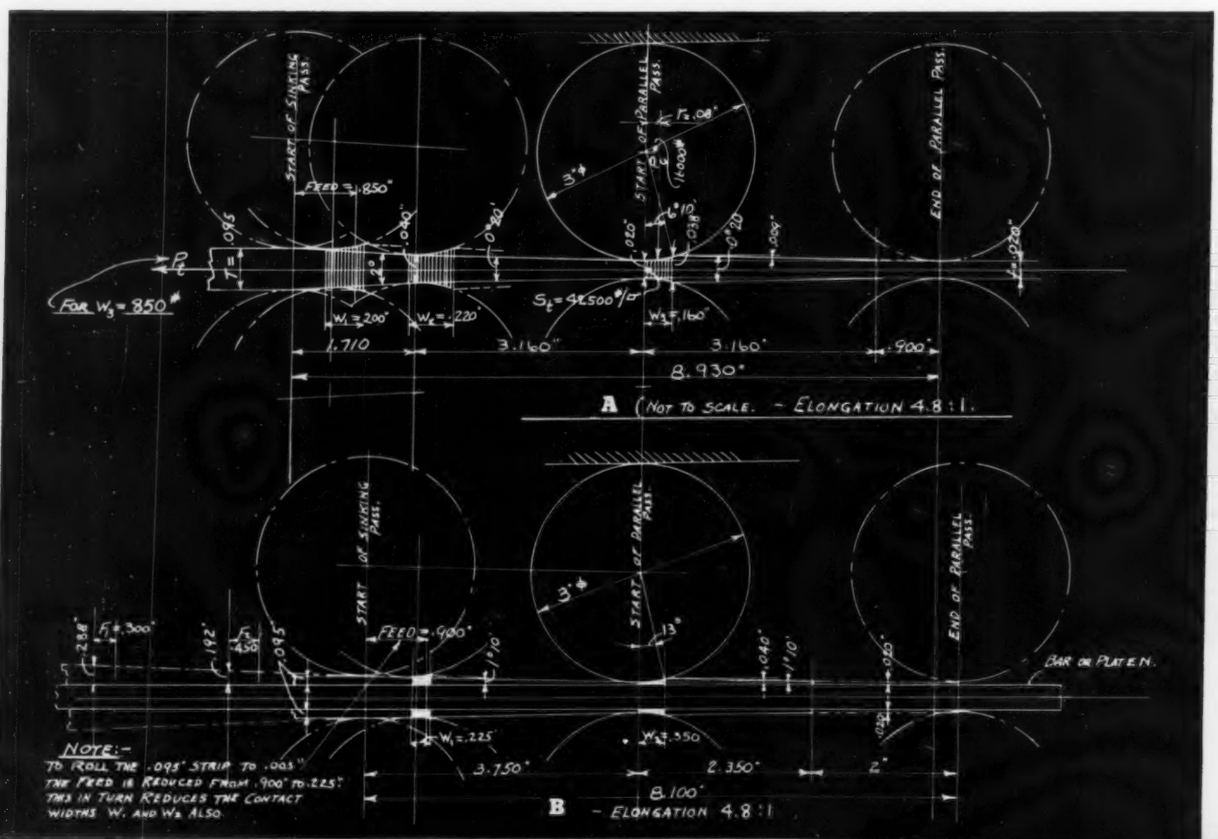


TABLE II—DATA FROM COLD ROLLING STRIP STEEL
Size of Coil .245 x 29 3/8" Wide.—Work Rolls 16" Diameter—Back-up Rolls 54" Diameter

Pass Number	Per Cent Reduction in Pass	Thickness of Strip Leaving Rolls	Length of Strip Leaving Rolls	Speed of Rolls (ft./min.)	Rolling Time (minutes)	Recorded HP of Mill Motor	Recorded Metal Pressure (lb.)	Metal Pressure per Inch Width of Strip (lb.)	Projected Contact Area (sq. in.)	Metal Pressure (lb./sq. in. of projected contact area	Bite or Contact Angle (degrees)
Enter	....	.245"	100 ft.								
1	31.4	.168"	145 ft.	350	.42	2200	1,600,000	54,000	.787	69,000	5½
2	37.5	.105"	232 ft.	400	.58	2400	1,600,000				5
3	41	.062"	395 ft.	350	1.12	2400	1,700,000	58,000	.590	99,000	4½
4	37.1	.039"	630 ft.	500	1.26	1800	1,600,000				3
5	35.9	.025"	980 ft.	500	1.96	1500	1,600,000				2½
6	40	.015"	1630 ft.	550	2.96	1200	1,750,000	60,000	.280	210,000	
7	17.3	.0124"	1970 ft.	500	3.94	700	1,650,000				

TOTAL ROLLING TIME = 12.28 minutes (at above roll speeds).
Assuming 5 minutes as time lost in operation of mill from coil, then time required = 17 minutes.
NOTE: In regular production the above strip is rolled in 9 passes with one anneal after the 4th pass.

and causes spreading due to the upsetting action of the forward slip of the metal at the gorge of the pass.

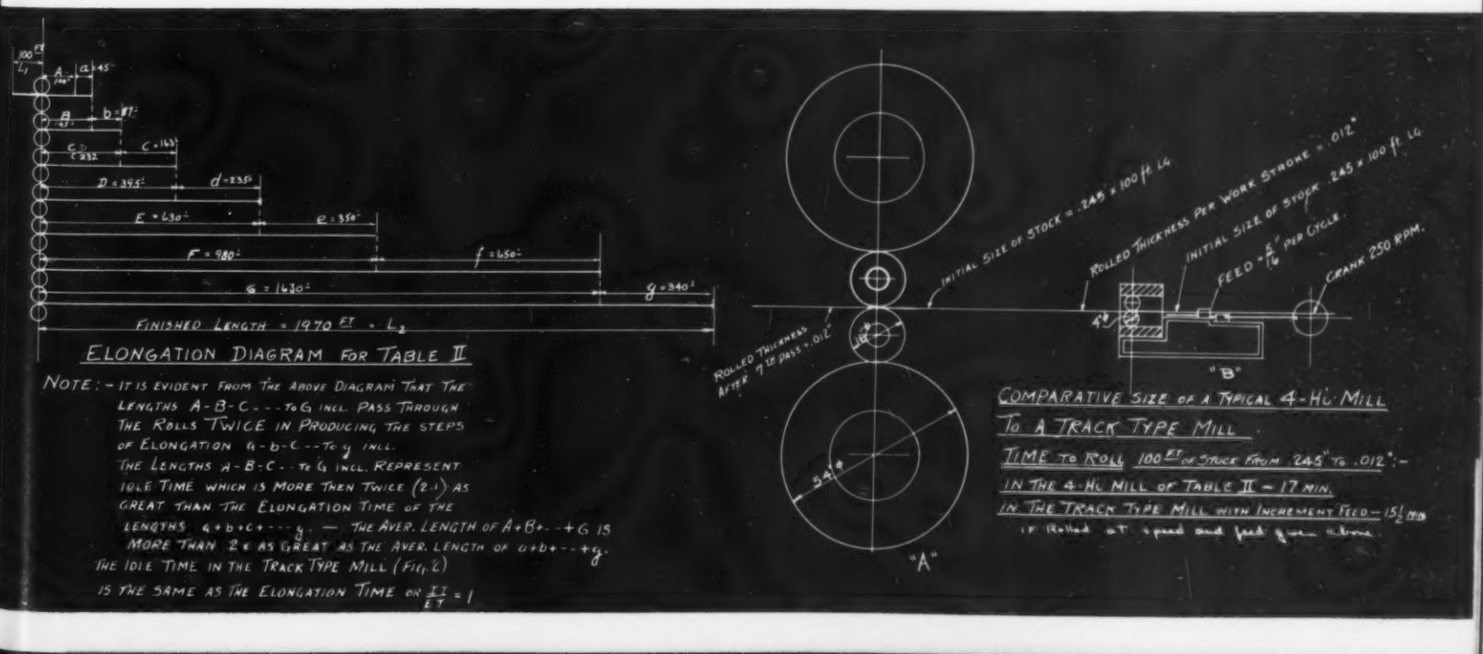
In the "Krause" process, the contact angle of the bar with the rolls can be extended far beyond the friction angle between the bar and rolls as shown in Figure 7. The metal in contact with the rolls between the lines "e" and "f" is outside said friction angle and flows in the direction of arrow "m".

As the tangential component of the normal pressure "P" is at all points within the area from "e" to "f" greater than the tangent of the friction angle "a", none of the metal displaced here tends to flow in the direction of arrow "n". Then again, the compressing forces acting on the bar between "e" and "f" tend to expel it out of the pass. This, however, is resisted by the force "F" pulling on the bar and the forces acting on the wedge portion of the bar (a-b) on the left side of the center-line of the rolls. The result is that the entire portion of the bar in contact with the rolls is not only under compression from the rolling forces but it is also under tension. Due to the tension forces, part of the bar from the right side of the center line of the rolls is drawn through the gorge of the pass as in a die. This drawing action may extend well beyond the no-slip, or neutral point "x" shown in the diagram. The rest of the bar is drawn and elongated in the direction of arrow "m" under tension and compression.

A further study of Figures "a", "b" and "c" of Figure 4 shows that by increasing the wedge angle from 3 degrees in case "a" to 6 degrees in case "b", the sinking stroke of the rolls is reduced at the expense of the projected contact width, from .530" to .670".

The greatest torque of the rolls and pull on the bar in the parallel pass is exerted at the beginning of that

FIGURE 13—Elongation diagram from an existing mill, from test run shown in Table II. To the right is a comparison of size of this mill to that of a Krause mill of the same capacity.


ELONGATION DIAGRAM FOR TABLE II
FINISHED LENGTH = 1970 FT = L2
NOTE:- IT IS EVIDENT FROM THE ABOVE DIAGRAM THAT THE LENGTHS A-B-C---TO G INCL. PASS THROUGH THE ROLLS TWICE IN PRODUCING THE STEPS OF ELONGATION a-b-c--TO g INCL.
THE LENGTHS A-B-C--TO G INCL. REPRESENT IDLE TIME WHICH IS MORE THEN TWICE (2.1) AS GREAT THAN THE ELONGATION TIME OF THE LENGTHS a+b+c+---g — THE AVER. LENGTH OF A+B+--+G IS MORE THAN 2 x AS GREAT AS THE AVER. LENGTH OF a+b+--+g.
THE IDLE TIME IN THE TRACK TYPE MILL (FIG. 2) IS THE SAME AS THE ELONGATION TIME OR L2/L1 = 1
INITIAL SIZE OF STOCK = .245 x 100 ft. LG
ROLLED THICKNESS PER WORK STROKE = .012"
INITIAL SIZE OF STOCK .245 x 100 ft. LG
FEED = 5/16" PER CYCLE.
CRANK 250 RPM.
ROLLED THICKNESS AFTER 7 TH PASS = .012"
54"ø
"A"
"B"
COMPARATIVE SIZE OF A TYPICAL 4-HI MILL TO A TRACK TYPE MILL
TIME TO ROLL 100 FT OF STOCK FROM .245" TO .012":-
IN THE 4-HI MILL OF TABLE II — 17 MIN.
IN THE TRACK TYPE MILL WITH INCREMENT FEED — 15½ MIN
IF ROLLED AT SPEED AND FEED GIVEN ABOVE

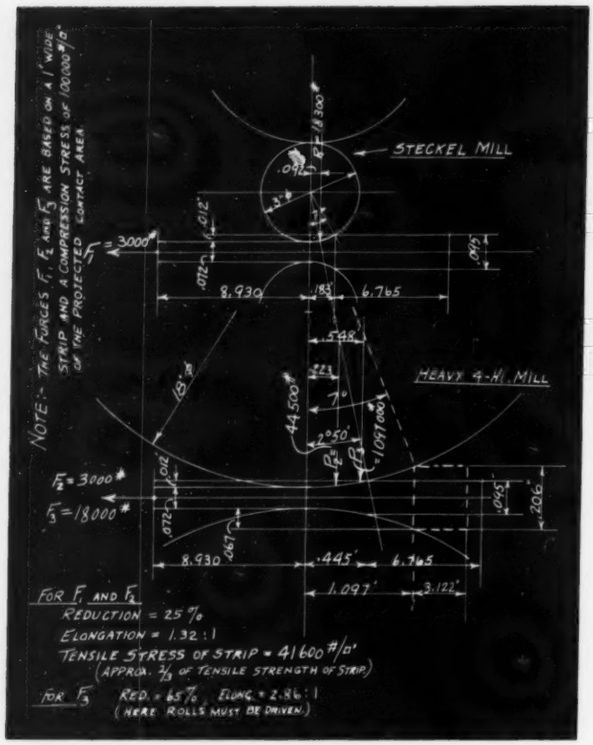


FIGURE 11—Comparison of rolling on Steckel mill and on a heavy four-high mill.

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FIGURE 12—(A) Conditions arising in Krause mill when rolling same strip as in Figure 11. (B) Two strips may be rolled simultaneously with a flat bar as a mandrel between them in the Krause mill.

direction of rolling, the tendency of the rolls is to draw a greater volume of metal into the pass than can flow out of it. The result is a crowding of the metal in the pass and slippage of the rolls on the bar accompanied by spreading and an increase of the flow stress of the metal. Now in the operation of the rolls in "a" of Figure 4 the metal is displaced principally ahead of the vertical center-line of the rolls in a pass with diverging surfaces in the direction of rolling in which the metal can flow away quite freely. Therefore, the metal is displaced in a natural way—the line of least resistance. Within this pass, the metal is displaced in a progressively increasing volume as the space in the pass increases also.

Another point in favor of displacing the metal as in "a", Figure 4, (the Krause process) is that the contact angle of the rolls with the blank can be many times greater than the friction angle for the material of the blank and rolls, thereby reducing the flow resistance of the metal. Whereas, in the conventional mills with driven rolls, the contact width *must* be within said friction angle so that the bar may enter the pass. In the first case, the draft *is not* limited by the coefficient of friction for the rolls and the bar, but in the latter case, the draft is definitely limited by the coefficient of friction for rolls and bar.—See Figures 7 and 8.

Figure 7 shows the principle of the metal displacement in the "Krause" mill. In the conventional rolling mill process, the no-slip point of the metal in contact with the rolls is ahead of the middle of the contact angle "a", say at "x", therefore, relative to the surface of the rolls, the metal in the pass between the lines "b" and "c" flows forward and is extruded in the direction of rolling, whereas, the metal between the lines "c" and "e" flows backwards thereto. The metal within this zone (b to e) is resisted in its flow by the friction between the bar and rolls which results in an increase of the unit compression or flow stress of the material

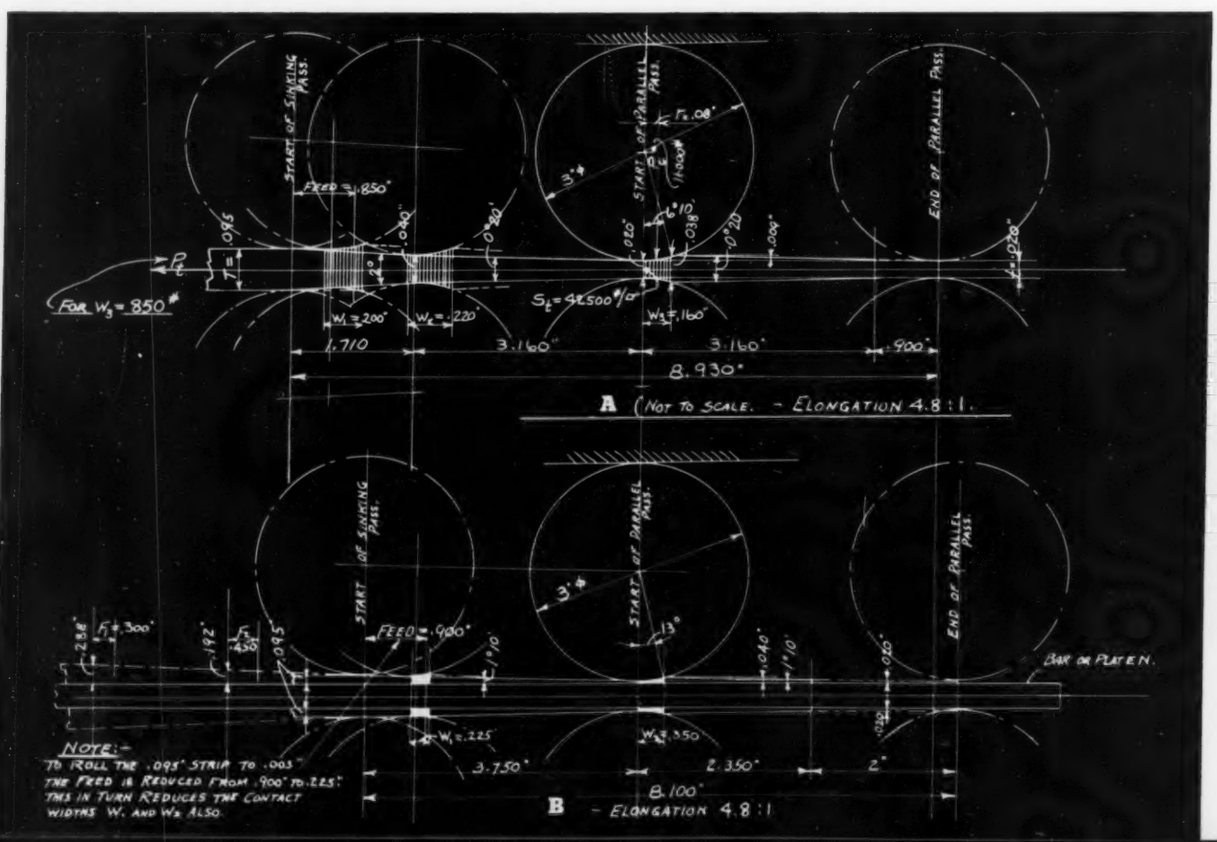


TABLE II—DATA FROM COLD ROLLING STRIP STEEL
Size of Coil .245 x 29 3/8" Wide.—Work Rolls 16" Diameter—Back-up Rolls 54" Diameter

Pass Number	Per Cent Reduction in Pass	Thickness of Strip Leaving Rolls	Length of Strip Leaving Rolls	Speed of Rolls (ft./min.)	Rolling Time (minutes)	Recorded HP of Mill Motor	Recorded Metal Pressure (lb.)	Metal Pressure per Inch Width of Strip (lb.)	Projected Contact Area (sq. in.)	Metal Pressure (lb./sq. in. of projected contact area	Bite or Contact Angle (degrees)
Enter	....	.245"	100 ft.								
1	31.4	.168"	145 ft.	350	.42	2200	1,600,000	54,000	.787	69,000	5½
2	37.5	.105"	232 ft.	400	.58	2400	1,600,000				5
3	41	.062"	395 ft.	350	1.12	2400	1,700,000	58,000	.590	99,000	4½
4	37.1	.039"	630 ft.	500	1.26	1800	1,600,000				3
5	35.9	.025"	980 ft.	500	1.96	1500	1,600,000				2½
6	40	.015"	1630 ft.	550	2.96	1200	1,750,000	60,000	.280	210,000	
7	17.3	.0124"	1970 ft.	500	3.94	700	1,650,000				

TOTAL ROLLING TIME = 12.28 minutes (at above roll speeds).
Assuming 5 minutes as time lost in operation of mill from coil, then time required = 17 minutes.
NOTE: In regular production the above strip is rolled in 9 passes with one anneal after the 4th pass.

and causes spreading due to the upsetting action of the forward slip of the metal at the gorge of the pass.

In the "Krause" process, the contact angle of the bar with the rolls can be extended far beyond the friction angle between the bar and rolls as shown in Figure 7. The metal in contact with the rolls between the lines "e" and "f" is outside said friction angle and flows in the direction of arrow "m".

As the tangential component of the normal pressure "P" is at all points within the area from "e" to "f" greater than the tangent of the friction angle "a", none of the metal displaced here tends to flow in the direction of arrow "n". Then again, the compressing forces acting on the bar between "e" and "f" tend to expel it out of the pass. This, however, is resisted by the force "F" pulling on the bar and the forces acting on the wedge portion of the bar (a-b) on the left side of the center-line of the rolls. The result is that the entire portion of the bar in contact with the rolls is not only under compression from the rolling forces but it is also under tension. Due to the tension forces, part of the bar from the right side of the center line of the rolls is drawn through the gorge of the pass as in a die. This drawing action may extend well beyond the no-slip, or neutral point "x" shown in the diagram. The rest of the bar is drawn and elongated in the direction of arrow "m" under tension and compression.

A further study of Figures "a", "b" and "c" of Figure 4 shows that by increasing the wedge angle from 3 degrees in case "a" to 6 degrees in case "b", the sinking stroke of the rolls is reduced at the expense of the projected contact width, from .530" to .670".

The greatest torque of the rolls and pull on the bar in the parallel pass is exerted at the beginning of that

FIGURE 13—Elongation diagram from an existing mill, from test run shown in Table II. To the right is a comparison of size of this mill to that of a Krause mill of the same capacity.

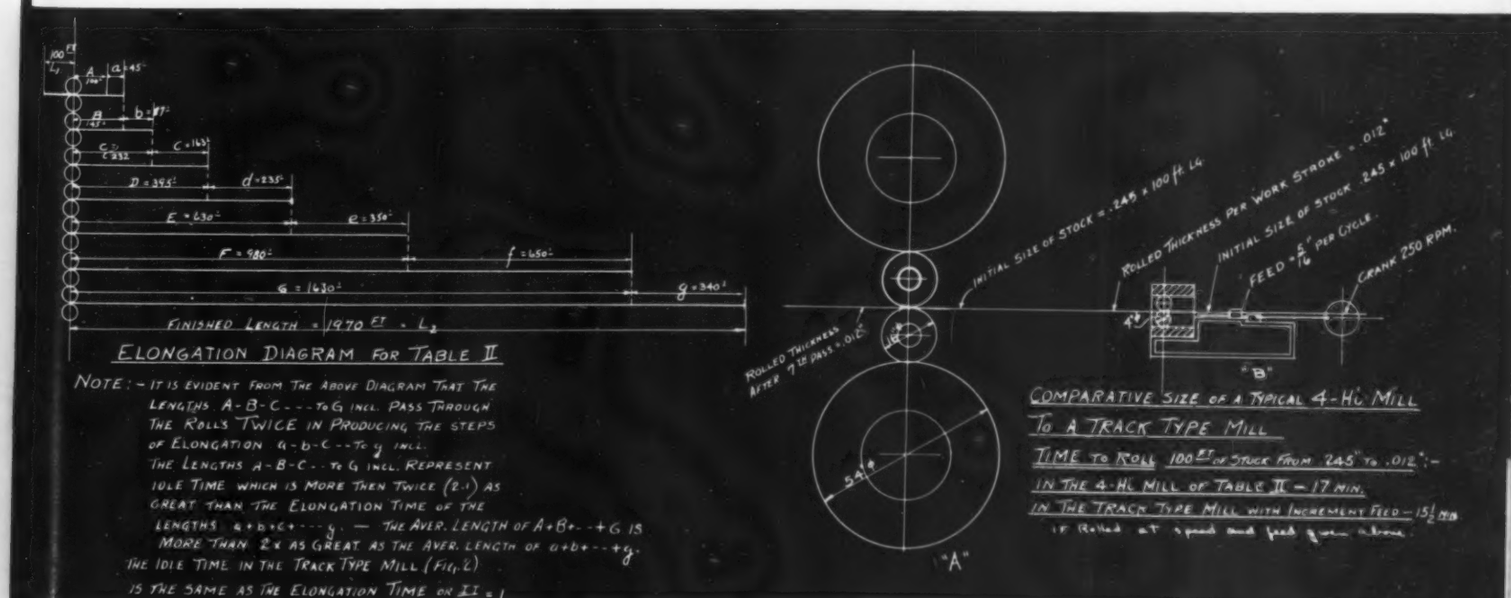

ELONGATION DIAGRAM FOR TABLE II
NOTE:- IT IS EVIDENT FROM THE ABOVE DIAGRAM THAT THE LENGTHS A-B-C---TO G INCL. PASS THROUGH THE ROLLS TWICE IN PRODUCING THE STEPS OF ELONGATION a-b-c--to g incl.
THE LENGTHS A-B-C--TO G INCL. REPRESENT IDLE TIME WHICH IS MORE THEN TWICE (2.1) AS GREAT THAN THE ELONGATION TIME OF THE LENGTHS a+b+c+---g. — THE AVER. LENGTH OF A+B+--+G IS MORE THAN 2x AS GREAT AS THE AVER. LENGTH OF a+b+--+g.
THE IDLE TIME IN THE TRACK TYPE MILL (FIG. 2) IS THE SAME AS THE ELONGATION TIME OR II/I = 1
INITIAL SIZE OF STOCK = .245 x 100 ft. LG.
ROLLED THICKNESS PER WORK STROKE = .012"
FEED = 5/16" PER CYCLE
CRANK 250 R.P.M.
ROLLED THICKNESS AFTER 7 1/2 PASS = .012"
54"
"A"
"B"
COMPARATIVE SIZE OF A TYPICAL 4-HI MILL TO A TRACK TYPE MILL
TIME TO ROLL 100 FT. OF STOCK FROM .245" TO .012":-
IN THE 4-HI MILL OF TABLE II — 17 MIN.
IN THE TRACK TYPE MILL WITH INCREMENT FEED — 1½ MIN
IF Rolled AT speed and feed given above.

TABLE III.

POWER REQUIRED IN KRAUSE MILL FROM ROLLED TESTS

Description	Case 1	Case 2	Case 3
Bar Entering Mill	3/16 x 6″	3/16 x 8″	.137 x 12″
Strip Leaving Mill	.015″	.022″	.030″
Elongation	12:1	8:1	4½:1
Feed	3/16″	.200″	7/32″
R.P.M. of Crank Shaft	60	60	60
Amps. (Peak Load)	175	225	150
Length of Strip Rolled per Stroke	2¼″	1.6″	1″
Length of Strip Rolled per Minute	11′–3″	8′–0″	5′–0″
Peak Load H.P.	50	65	43
Mean Power H.P.—Approx.	17	22	14

NOTES—Mill operated with 75 H.P., D.C. Motor, 600/1200 R.P.M., 220 Volts.
Mean Power H.P. = 1/3 Peak Load H.P. (Approx.)

pass at "b" and is the critical point from the strength standpoint of the bar in a single slope track system. In a multi-slope or reverse curve track-plate, this critical point can be shifted to almost any point in the sinking pass of the mill where the bar is stronger.

Comparing Cases "b" and "c", it is seen that by increasing the elongation from 2½ to 1, to 10 to 1, retaining the same wedge angle of 6 degrees and the same length of finished bar, three things happen:

1. The feed changes from 1.8″ to .448″.
2. The projected contact width becomes less and changes from .670″ to .530″.
3. The sinking stroke (wedge length) increases from 2.875 to 4.327″.

From this we can see:

(a) Any elongation can be made from a bar in a mill without changing track plates.

(b) The smaller the wedge angle of the bar at the beginning of the parallel pass, the less the strain and wear and tear on the machine.

Figure 9 shows a reproduction of a 3/8 x 3″ wide steel test bar rolled to show the condition developing in the rolling operation and to prove there is no slippage of

FIGURE 14—Rolling and production diagrams of a Krause mill when rolling the products set forth in Figure 10.

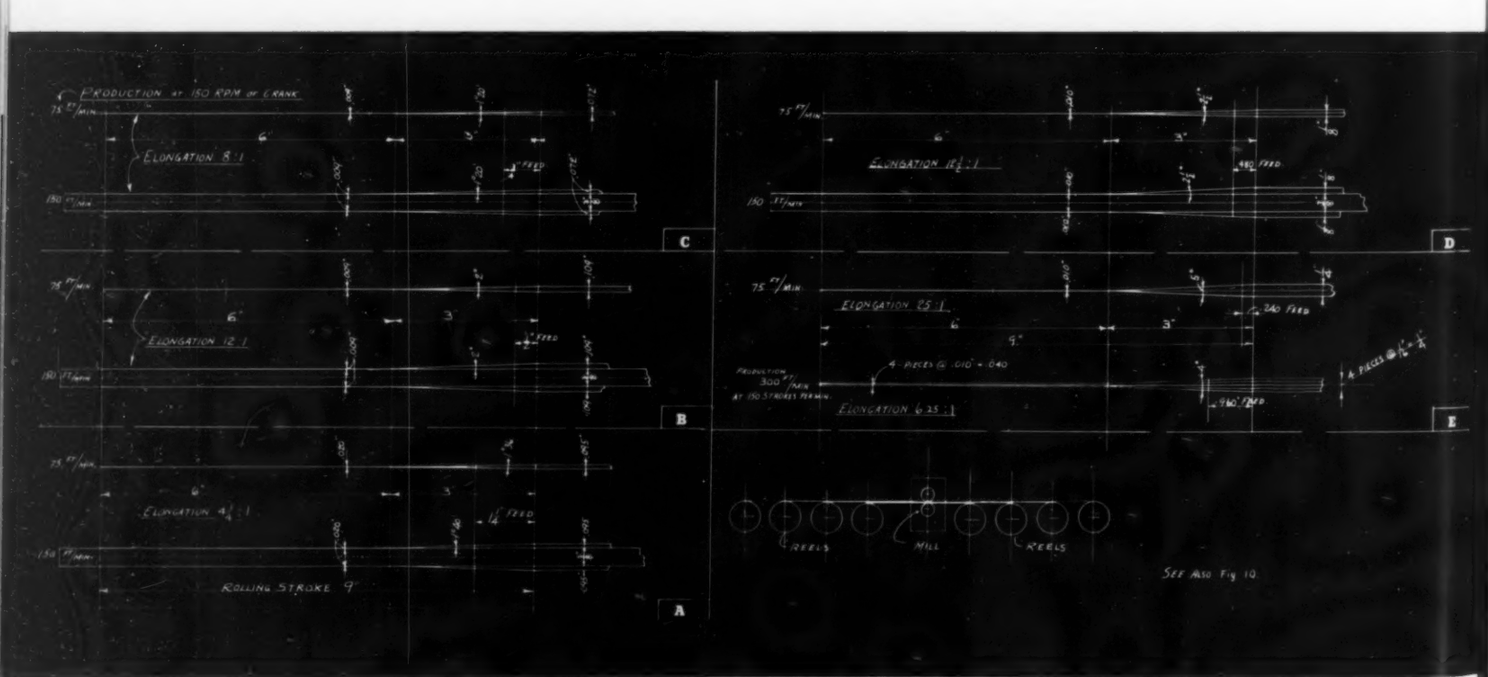


TABLE IV.

POWER REQUIRED IN CONVENTIONAL ROLLING MILLS TO ROLL THE SAME SIZE BARS WITH LIKE REDUCTIONS AND SPEED AS SHOWN IN TABLE III

Sym.	Description	Case 1	Case 2	Case 3
T	Bar Entering Mill	3/16 x 6″	3/16 x 8″	.137 x 12″
t	Strip Thickness Leaving Mill	.015″	.022″	.030″
d	Draft per Roll	.086	.082	.052
A	Contact Angle	17°	16½°	13°
W	Contact Width	.580″	.570″	.450″
PCA	Projected Contact Area—Sq. Inches	3.5″	4.56″	5.4″
r	Torque Radius	.35″	.34″	.27″
P	Separating Force	350,000	456,000	540,000
M	Torque Inch Lbs.	122,000	155,000	146,000
E	Tangential Effort—Lbs.	61,000	77,500	73,000
L	Length of Strip Rolled per Minute	11′–3″	8′–0″	5′–0″
HP	Power Required (2 Rolls)	42	38	24

NOTES—Metal pressure assumed at 100,000 lbs. per sq. inch proj. contact area.
Deformation of rolls and bearing friction etc., are not included in above calculations.

the rolls anywhere. In this case, a 25 hp. motor was taxed until it stalled by kicking out the circuit breaker.

Figure 10 shows three 4-high Reversing Cold Strip production cases which were given as typical cases by people who are reliable and should know. However, they have not been verified as yet. The diagrammatic illustrations of the passes and the data accompanying them need no further explanation.

Figure 11, shows near the top of the sheet the conditions arising in the first pass of the "Steckel" mill case shown on Figure 10. Reducing the .095″ thick strip 25 per cent is about the limit of reduction this mill can take on account of the high tensile stress of the strip from the pulling force "F_1". Incidentally, the 7 degrees contact angle of the rolls with the strip also is the limit of the bite capacity of cold strip mill rolls.

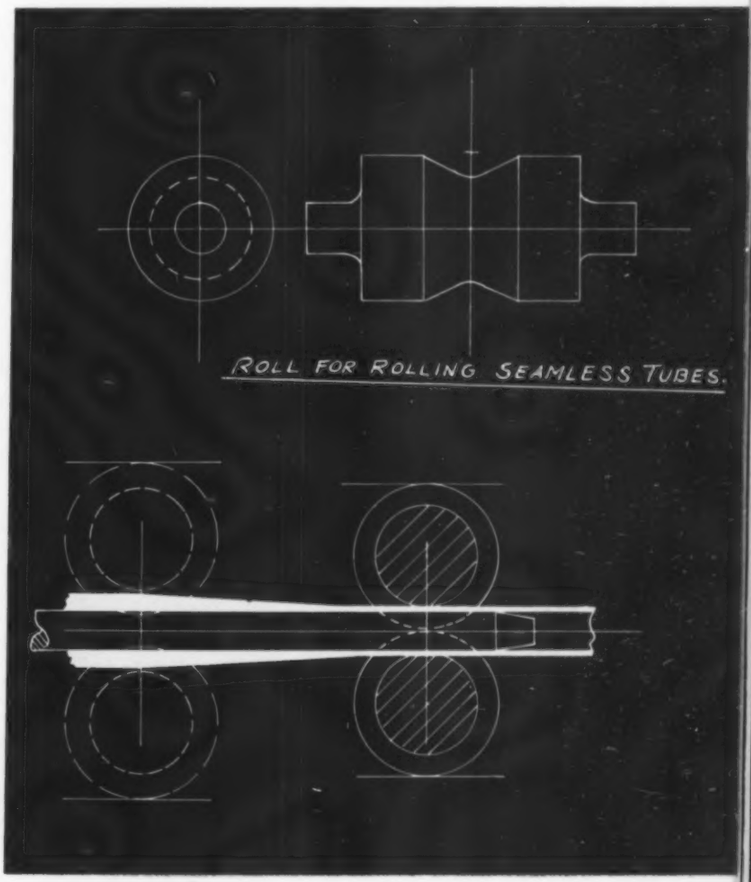
Further down on this figure there is shown for comparison the same strip rolled in a like manner in an 18″ mill. From these it may be observed that:

1. The contact angle of the rolls with the strip is much greater for the same draft in the 3″ mill than in the 18″ mill.
2. The tangential force required in each case is the same, i.e. $F_1 = F_2$.
3. The contact width of the rolls with the strip and the resulting separating force is 2.4 times greater in the 18″ than in the 3″ mill.

It is evident that the 18″ diameter roll is underloaded from the separating force "P_2" because the crushing strength of the 18″ diameter roll is six times greater than the crushing strength of the 3″ diameter roll and the contact width of the rolls with the strip on the 18″ diameter roll is only 2.4 times greater than on the 3″ diameter roll.

For an equal stress condition, the 18″ diameter rolls can stand 6 times the load of the 3″ diameter rolls, therefore, the entering thickness of the strip may be increased to .206″ as shown in dotted lines. However, to roll this strip to .072″ requires 6 times as much power

FIGURE 15—Seamless tubes can also be reduced by the Krause process, as here shown.



(a) Original structure. x 500. (b) First stage of reduction. x 500. (c) Second stage of reduction. x 500. (d) Final stage of reduction. x 5

FIGURE 16—Metal structure from a bar cold reduced by the Krause process. Taken pregressively along the shoulder of the reduction.

as the former cases, otherwise the drawing is self explanatory.

On Figure 12, there is shown in "A" the conditions arising when the same strip is rolled in a "Krause" mill from .095″ to .020″ in one operation (pass) instead of rolling it in 5 passes as is done in the Steckel mill previously referred to. The greatest tensile stress in the strip under the load "Pt" is at "W_3" and equals 42,500 lbs. per square inch, which is about the same as the tensile stress of the strip rolled in the Steckel mill in which the reduction of the strip was from .095″ to.072″ only. The separating force in this case remains about the same as in the Steckel mill but the crushing stress of the rolls is only about one-half as great.

In Figure 12-B, two strips are shown rolled with a flat bar as a mandrel between them.

In this process, we are independent of the coefficient of friction limiting the bite of the rolls. The contact angle of the rolls with the strip can be increased beyond the friction angle between the roll and the strip, also the contact width of the rolls with the strip can be made approximately twice as great as in the Steckel mill because the rolls are backed up with flat surfaces. (An infinitely large diameter roll.)

The crushing stress of rolls backed up in this way is no greater under a load that is twice as great as the load of a similar roll backed up by another roll.

Therefore as is seen from this drawing, the production in this mill can be greatly increased.

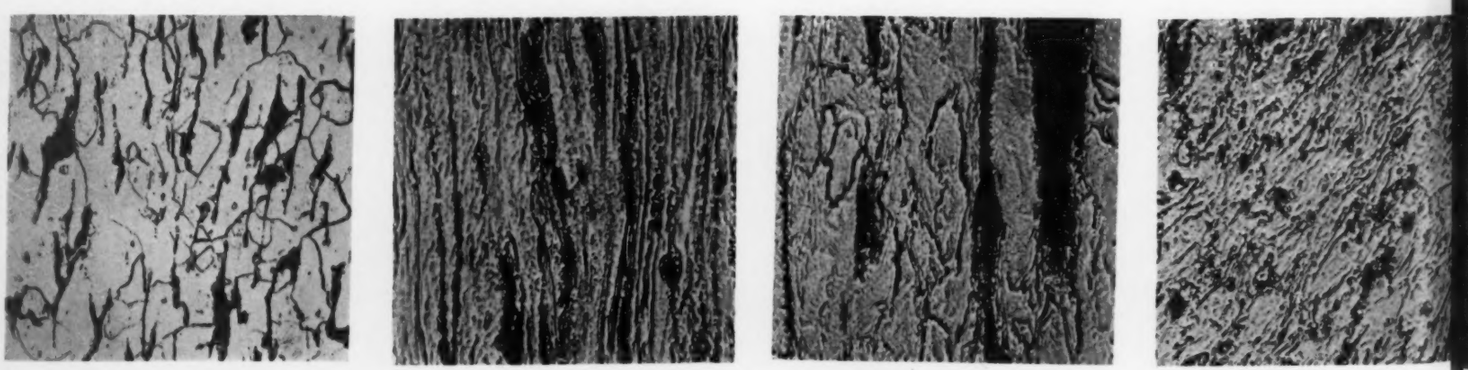
Another advantage of rolling strip in this manner is that very thin gauges can be rolled without exceeding the permissible tensile stress of the strip.

Table II shows the recorded data from a test run in a well-known mill. Figure 13 shows the lengths rolled and the elongation made in each pass. As the length of the strip rolled in each pass is a fraction of the time required for the piece to go through the rolls, it is evident that the length of the path the roll surface traverses is much longer than the elongation secured. In the present case, an elongation of 1870 ft. was secured while the rolls traversed a length of 5982 ft., which is 3.2 times more than the elongation produced. Thus it is clear that an enormous amount of power is wasted.

"A" and "B" of the same figure serve to give an idea of the relative size of the 4-high mill from which the data in Table II was secured and a "Krause" mill drawn to the same scale and producing the same ton-

FIGURE 17—Metal structure from a seamless tube cold reduced by the process.

(a) Original structure of tube. x 200. (b) Reduced tube, longitudinal section. x 500. (c) Reduced tube, tangential section. x 500. (d) Reduced tube, transverse sect x 500.



nage or length of strip in the same or less time when operated at the feed and speed indicated.

In Figure 14, "A", "B" and "C", production possibilities of a Krause mill are shown for the products given in Figure 10 "A", "B" and "C" from other mills when rolling the same size stocks to like gauges either singly or in pairs. At "D" is shown the rolling of $\frac{1}{8}$" stock to .010" and at "E" is shown $\frac{1}{4}$" stock rolled to .010" or 4 strands of $\frac{1}{16}$" strip rolled each to .010" as in pack rolling.

Experiments have shown that seamless tubes can be reduced by this process as well as flat bars or strip. To roll tubes by this process, it is not necessary to have tapered grooves as in the Coe or Pilger mills. The rolls are small in diameter and have a concentric groove which forms a wide open pass as shown in Figure 15. In cold reducing the wall and diameter of the tube, a mandrel is used inside the tube, as also shown in Figure 15. An important feature of this mill is that several tubes can be rolled simultaneously at one time.

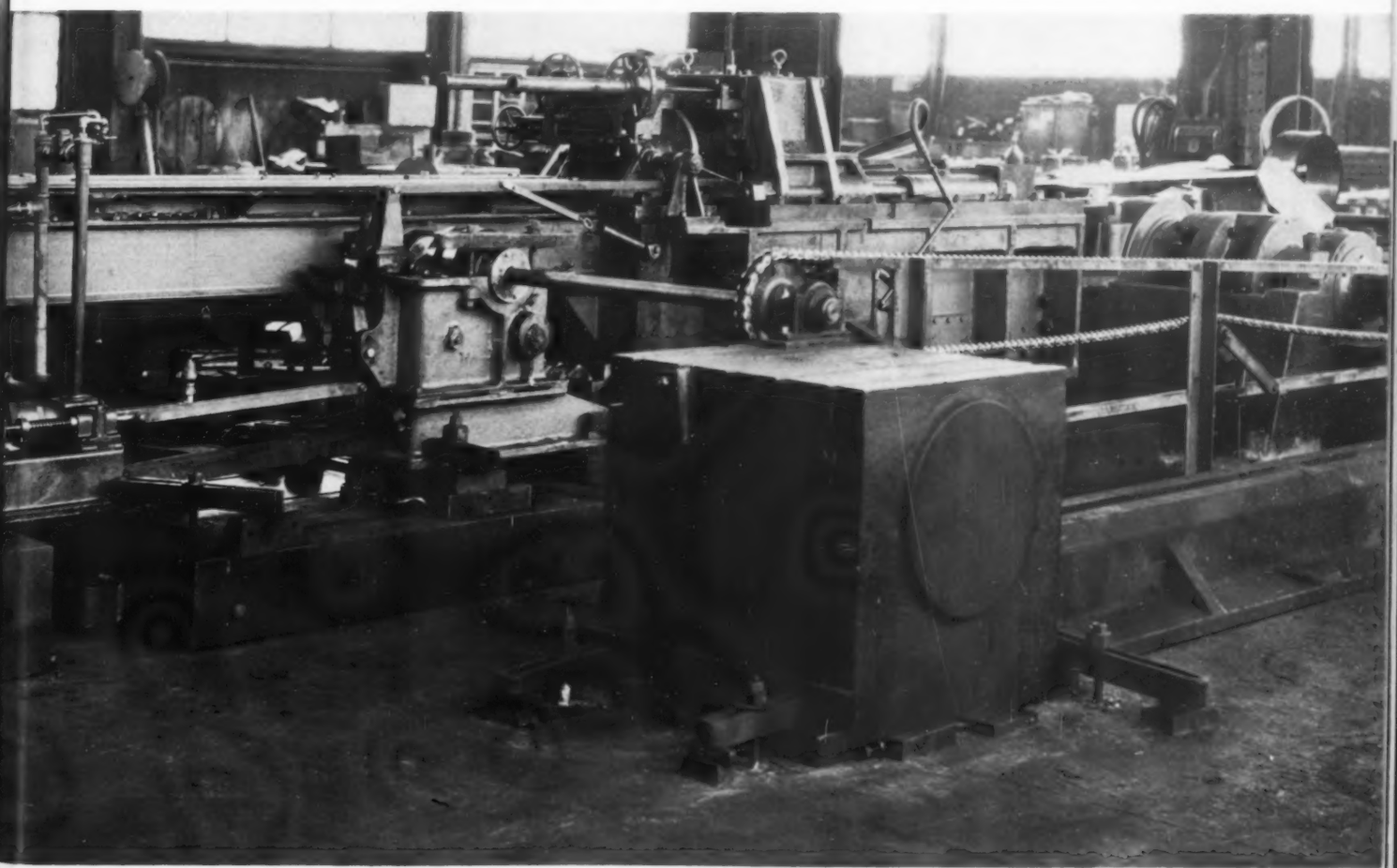
Seamless steel tubes have been experimentally rolled from $1\frac{1}{4}$" O.D. x $\frac{1}{4}$" wall to $\frac{13}{16}$" O.D. x $\frac{1}{32}$" wall.

In Figure 16 are shown micro photographs of the metal structure from a cold reduced bar from the Krause process. The bar, of low carbon, annealed stock, was reduced from $\frac{5}{8}$" x $\frac{1}{4}$" to .015", giving a reduction of about 15 times. Polished sections were prepared from the shoulder of the reduction in longitudinal planes parallel to the length of the strips and perpendicular to their broad surfaces. Etching was effected in 1 per cent picric acid followed by drying and subsequent immersion in .5 per cent nitric acid in alcohol. In the first stage of reduction, many grains have typical slip bands. Further reduction makes slip bands less apparent, whole longitudinal deformation lines, parallel to the direction of elongation, increasing materially.

The structure of a tube cold reduced by the Krause process is given in Figure 17. From an original size of $1\frac{5}{32}$" O.D. x $\frac{3}{16}$" wall, a product of $\frac{27}{32}$" O.D. x $\frac{1}{16}$" wall was formed. The structure shows narrow fibres paralleling the length of the tube, most of which display longitudinal deformation markings and are free from slip bands. No folds or other surface imperfections were found in this metal.

Patents for this process are now pending in the U. S. A., England, France, Germany, Sweden and Italy.

Another view of the mill housing, which is moved back and forth on the bed by crank and connecting rod. The mill operates in a speed range of 60 to 120 cycles per minute.



NEW *Continuous Pipe* MILL *at* SPANG CHALFANT

▲ ALTHOUGH the Fretz-Moon process for making butt-welded pipe has been used for a number of years, the equipment installed by Spang Chalfant, Inc., at their Etna, Penna. plant includes many new features and represents the latest development in the application of the process. Although the process itself is basically the same, in that a continuous strip of skelp is run through a heating furnace and a pipe welding mill, the conventional equipment has been materially improved in this installation.

Designed for a range of pipe sizes from ½″ up to 3″, the production line has a maximum capacity of about 20 tons per hour on the large sizes, and will average about 12 tons per hour in typical production. The unit was completed in March, and has been in operation about five months.

Coils, which form the raw material for the plant, are purchased on the outside, and stocked in a conveniently located storage building, from which they are withdrawn as desired. They are usually 35″–38″ in diameter, and weigh 600–1800 lb. each, depending on width. Each coil contains approximately 185–550 ft. of skelp. A scale has been provided so that accurate charged weights may be determined. After weighing in lots of six or eight at a time, the coils are placed individually on an uncoiling mandrel, from where the coil end is fed through a roller leveller and into a welding machine. Adjacent ends of successive coils are butted evenly together and flash welded, forming a continuous strip. The welder operates from a special transformer, under a voltage which is varied by tap-changing according to the thickness and width of the skelp. This voltage is of the order of 5 to 15 volts. The transformer has a capacity of 200 K.V.A., and uses 220 volt A. C. power on the primary side. A plow-type trimmer located immediately after the welder serves to remove the flash set up by the welder, and gives a smooth-surfaced welded joint.

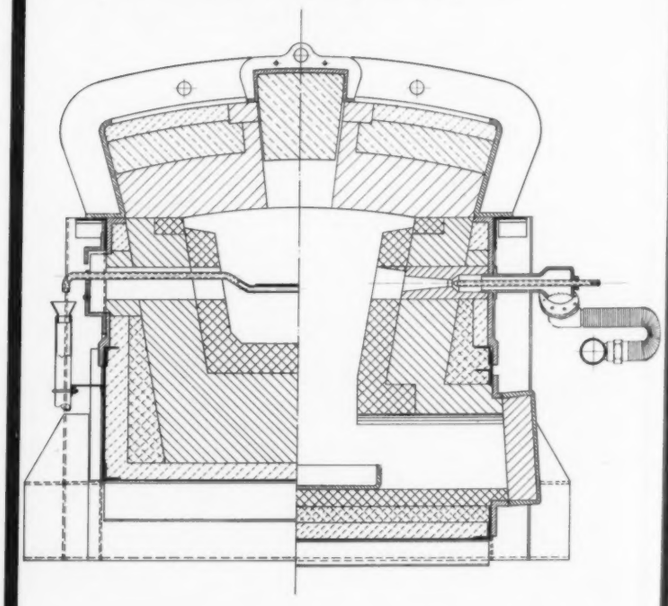
The strip is then pushed out by a set of pinch rolls onto a large looping table with a reinforced concrete facing. The loop thus formed allows continuous operation of the furnace and mill while the feed is stopped for welding successive coils together. Water is sprayed on the strip to serve as a lubricant as it passes over the looping table.

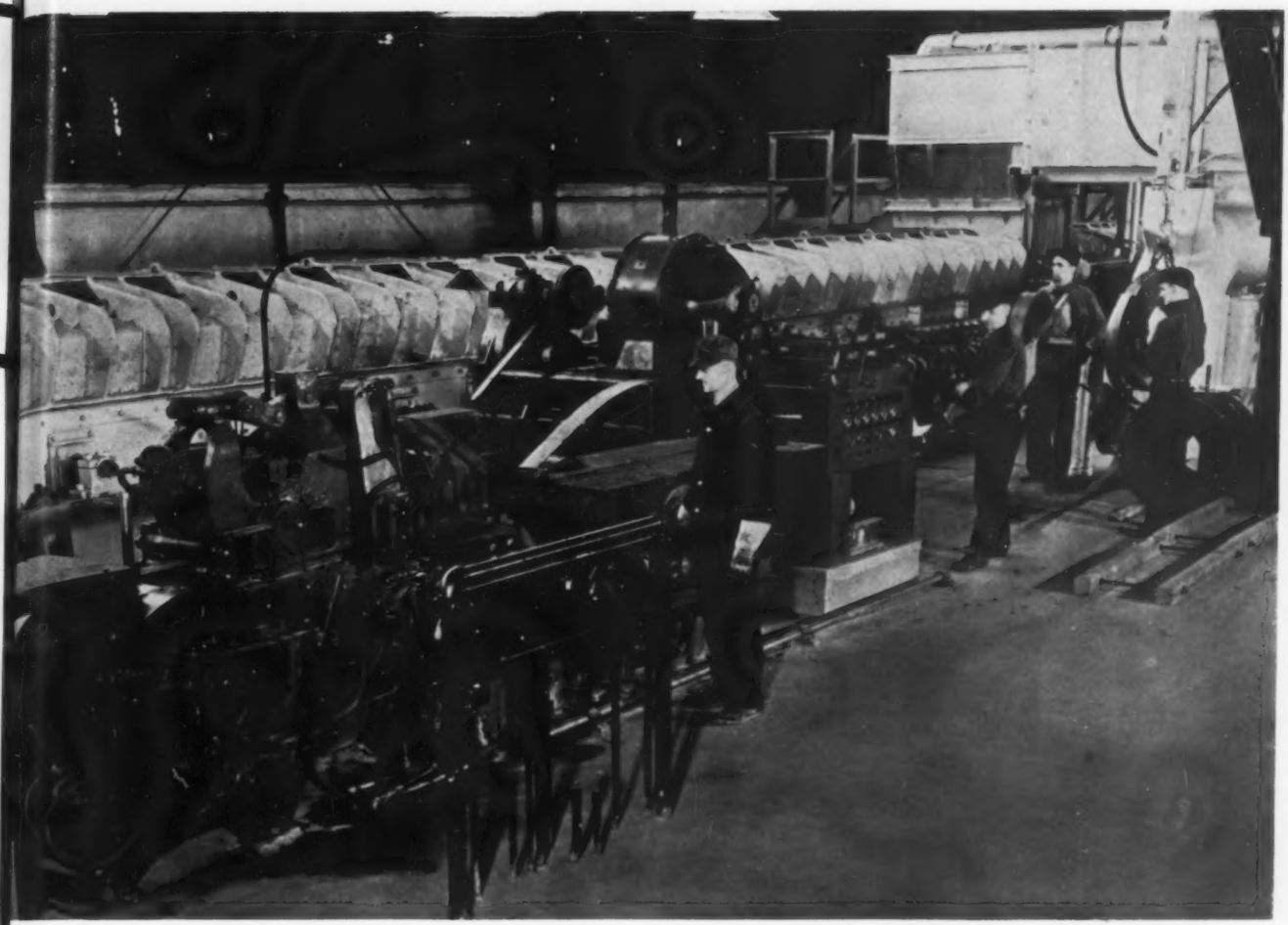
On the looping table, the skelp makes a 180 degree turn and is dragged back into furnace.

The heating operation, which is very important in this process, is carried out in a continuous furnace designed and built by the Salem Engineering Company, Salem, Ohio. The furnace is 146 ft. long, with a width of 16 inches at the bottom and 27 inches at the top, and a heating chamber height of 21 inches. The first 30 ft. of the furnace is devoted to a preheating chamber, and is not directly fired. The heating chamber, 116 ft. in length, is fired with 1100 B.t.u. per cu. ft. natural gas through 274 nozzle-mixing burners, each with a rated capacity of 175 cu. ft. of natural gas per hour. These burners are of special design so as to afford a wide range of flame adjustment, and are provided with spiral vanes in order to give rapid mixing and combustion. Total burner capacity is therefore about 48,000 cu. ft. per hour, although gas flow equipment for the furnace proper is based on not exceeding 40,000 cu. ft. of gas per hour. Air leads from the hot air headers to the burners are made of flexible tubing in order to allow for any expansion of the furnace structure due to the excessive temperature.

The heating chamber is divided into three separate

Cross-sectional view of continuous skelp heating furnace. The section through the heating zone, left, shows the cylindrical skid over which the strip passes. To the right is the section showing the slag pocket.





Stock from the uncoiling mandrel passes through a roller leveller and on to the electric welder and flash trimmer.

zones, each with its individual controls, recuperator and dilution air fan, so as to afford adequate furnace regulation. Each zone is equipped with fuel-air ratio control.

The recuperators, of which there are three, are composed of 21 chrome steel elements in which air for combustion is preheated to about 900 degrees F. by the waste products of combustion. Automatic temperature control is provided on each recuperator in order to properly govern preheat temperature, and to guard against recuperator temperature reaching the point at which the metallic elements would be injured. This is accomplished by diluting the products of combustion entering the recuperators with air, the air being controlled by a motor-operated valve actuated from a controlling pyrometer.

Temperatures of 1750–1850 degrees F. are usually maintained at this point. Each of the recuperators take about one-fourth of the products of combustion, the remainder passing out through the preheating chamber. This plan of preheating adds to the fuel economy of the unit. All of the flue gases are collected into one main flue located underground and leading to a stack just outside the building.

Gas pressure is maintained at about 8″ in the manifold, and combustion air, which is furnished for the entire furnace by a single blower, is held at a manifold pressure of about 7″ water column. Furnace pressure is maintained in an approximately balanced condition, while stack draft after the recuperators runs about .65″ water column.

All furnace controls and instruments are grouped on a central panel board, and include the following:

Three indicating controlling pyrometers for recuperator temperatures.

One three-point pyrometer recording the recuperator temperatures.

One radiation pyrometer recorder showing furnace temperature at the discharge end.

One selective indicating pyrometer which may be used on any one of ten points in the recuperative system.

Three draft indicators, showing the draft at a point where waste gases leave the recuperator.

One gauge giving the draft where waste gases leave the preheating chamber.

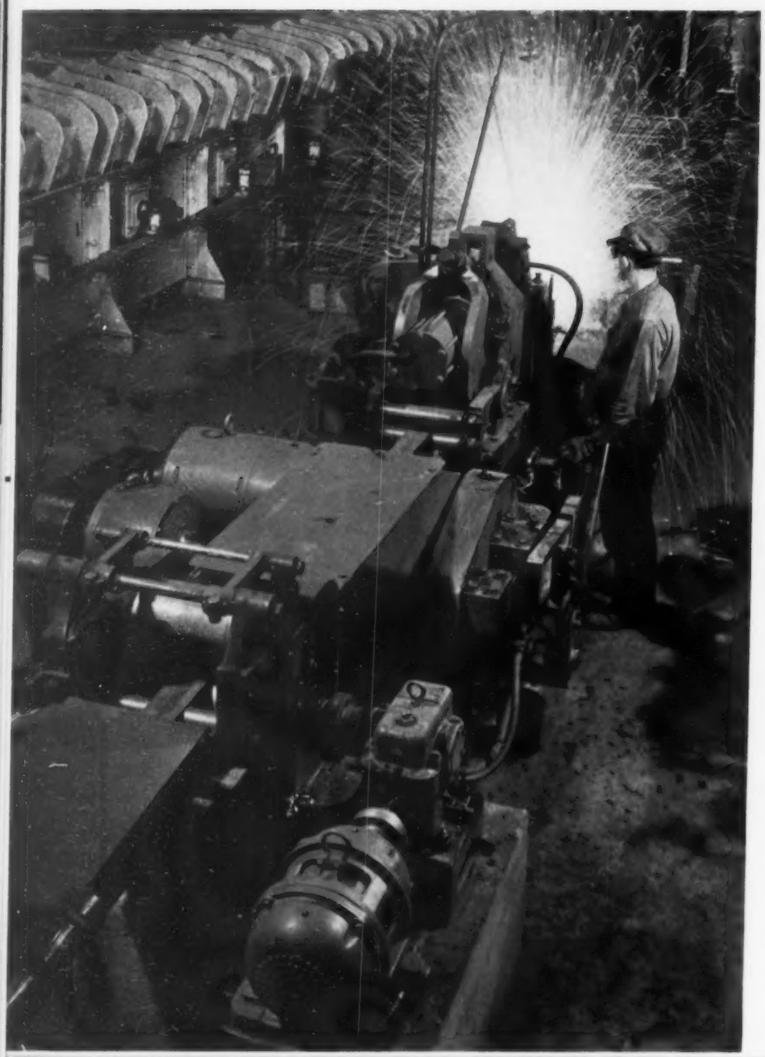
One gauge showing draft on the stack.

One recording tachometer showing strip speed in ft. per min.

One indicating and recording gas flowmeter.

Six indicating gauges showing gas and air pressure in each zone.

Three fuel-air ratio controls, with necessary gauges.



The roof of the furnace is made in sections, each section consisting of a cast steel bung, lined with high quality refractory. The bungs are easily removable in order to provide quick access to the interior of the furnace for maintenance purposes. The bottom of the furnace is made from chrome refractories, and is so designed that scale may be removed from slag pockets provided for the purpose. The high temperatures prevailing in the furnace, together with the action of the scale and slag formed, necessitate the use of high-grade refractories throughout the entire furnace structure.

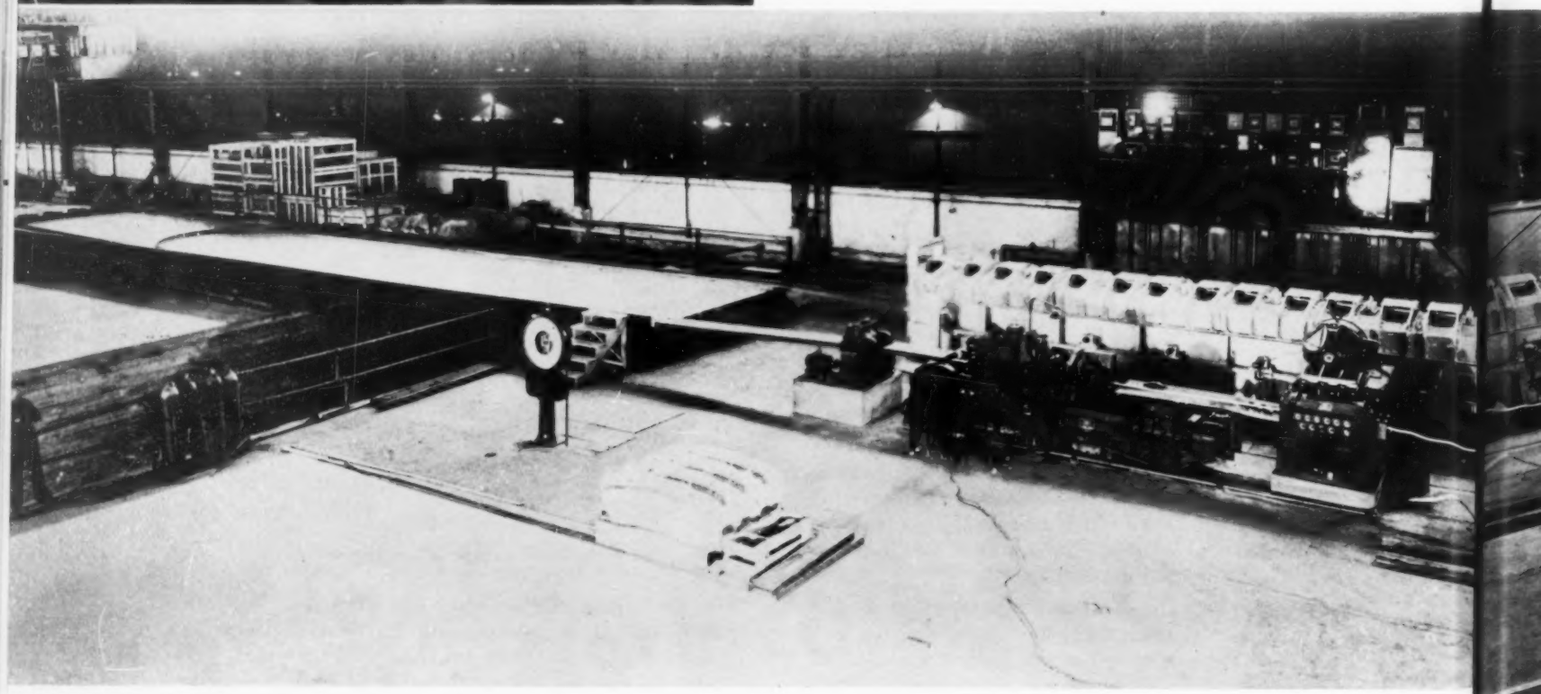
As the strip enters the furnace, it is carried through the preheating zone on a series of motor-driven heat-resisting alloy rolls. Each roll has its own chain drive so that a chain failure will not result in stoppage of all rolls. In the heating zone, the strip passes over tubular water-cooled skids.

As previously stated, the heating operation is of utmost importance in this process. Differing from the majority of steel plant heating problems, an uneven, or "flash" heat is necessary. The edges of the skelp must approach the softening point in order to insure proper welding, which calls for a temperature of approximately 2850 degrees F. Yet, as the strip is pulled through the furnace entirely by means of the pipe

Electric welder in action, forming the butt weld which joins two strips together. It is followed by the flash trimmer, and, in the left foreground, pinch rolls which push the strip out onto the looping table.

•

General view showing leveller, welder, trimmer and pinch rolls, followed by the looping table. At top right, electrical switches and controls are mounted on small balcony. In center foreground is a spare furnace roof bung.



welding mill at the discharge end of the furnace, it is essential that the center of the strip is not overheated, as it must retain enough strength to pull itself through. To aid in attaining this end, the burners on the furnace are so located as to impinge directly on the edges of the skelp. It is apparent, therefore, that all phases of the heating process must be under accurate control. Temperatures must be closely watched. Any variation from proper fuel-air ratios will badly impair fuel economy. Excess air will result in excessive scale loss. Furthermore, the small cross-section of the furnace and the high temperatures require extremely rapid combustion. This requirement is attested to by the fact that heat release runs in the neighborhood of 100,000 B.t.u. per hour per cu. ft. of furnace volume.

The furnace has a maximum capacity of about 20 tons per hour. Based on its hearth area of 195 sq. ft., this points to a production rate of over 200 lb. per hour per sq. ft. of hearth area. A heating rate as high as this is possible only for a "flash" heat such as used in this process. This point is further borne out by the fact that strip speeds, which range 75–300 ft. per min., allow a heating time of only about 2 to ½ minutes, with the furnace length of 146 feet.

The attention which was given to furnace design and regulation bears fruit in its economy of operation, an average operating fuel rate of about 2500 cu. ft. of gas per ton of product having been attained.

As the hot skelp emerges from the furnace, a blast of air from a blower is played on each of its edges, which causes an increase in temperature due to oxidation and at the same time serves to remove any loose scale and dirt. The skelp then passes through six pairs of grooved rolls, arranged into three sets, each set consisting of a pair of vertical and a pair of horizontal rolls. The first set are the forming rolls, taking the place of bells used in conventional pipe production lines, wherein the skelp is formed ready for welding. The second set of rolls begins the welding process, which is carried on in the subsequent rolls until the welded and properly sized pipe emerges from the sixth set of rolls. All of these rolls are driven from a single 15 H.P., 400/1600 R.P.M., 230 volt D.C. motor, through an extensive train of speed reducers and gearing. Overall gear ratios from drive motor to rolls are 13.84:1 on the first stand and 11.63:1 on the second and third stands. Strip speeds are adjustable over a range of 75 to 300 ft. per minute.

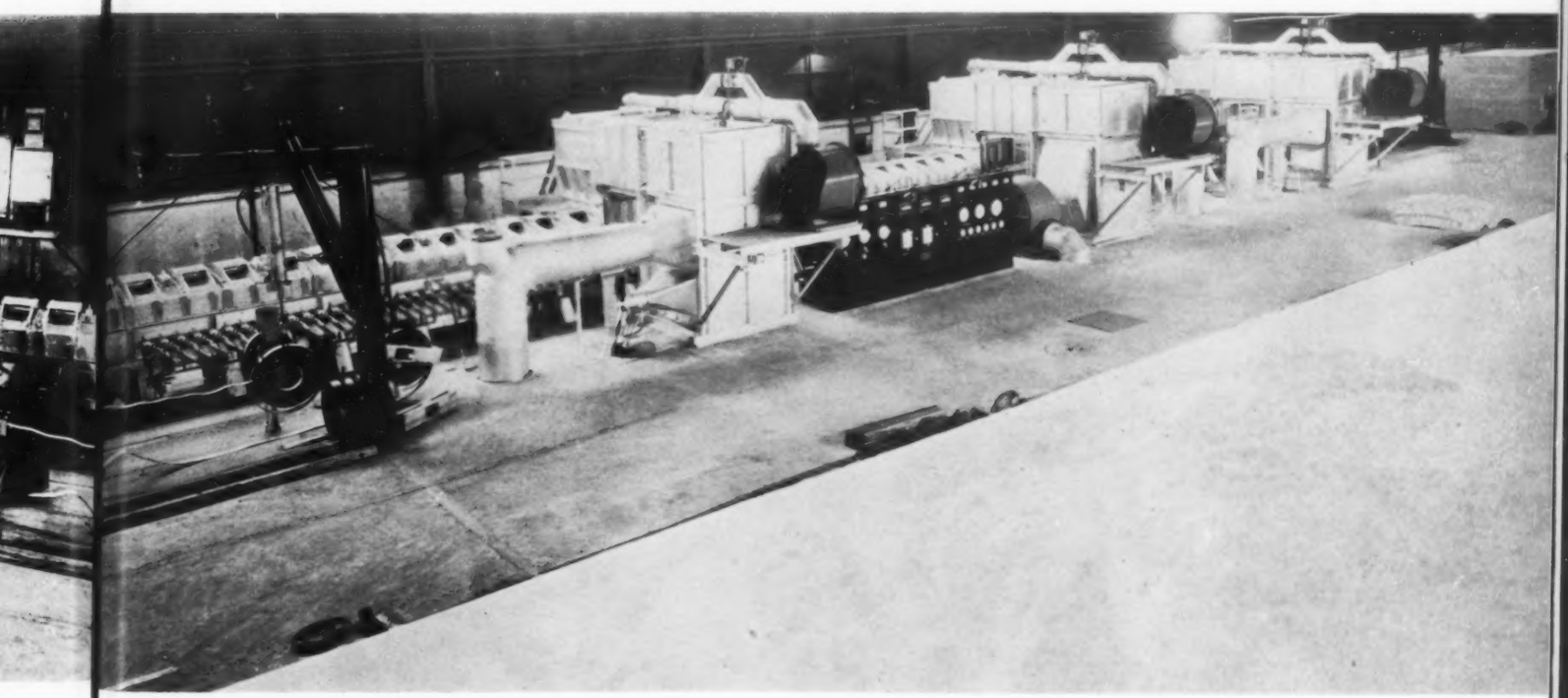
Following the welding mill is a flying hot-saw, which automatically cuts pipe into exact desired lengths. The saw is motor-driven, but the saw travel is driven from the welding mill motor through a variable speed reducer, so that the speed of the travel may be synchronized with the speed of the pipe from the mill.

After passing over a small cooling rack, the lengths of pipe are conveyed to a descaler consisting of three pairs of rolls, where scale is cracked loose, both externally and internally. The descaler consists of three pairs of rolls, all driven by a single 15 H.P., 400/1600 R.P.M., 230 volt D.C. motor.

From the descaler, the pipe is conveyed to a large cooling rack. After cooling, it is straightened, tested hydrostatically under 1000 lb. per sq. in. pressure, and finally threaded. Through the entire process, the scale loss is about 3 per cent, the most of which is caused by the air blast at the welding mill.

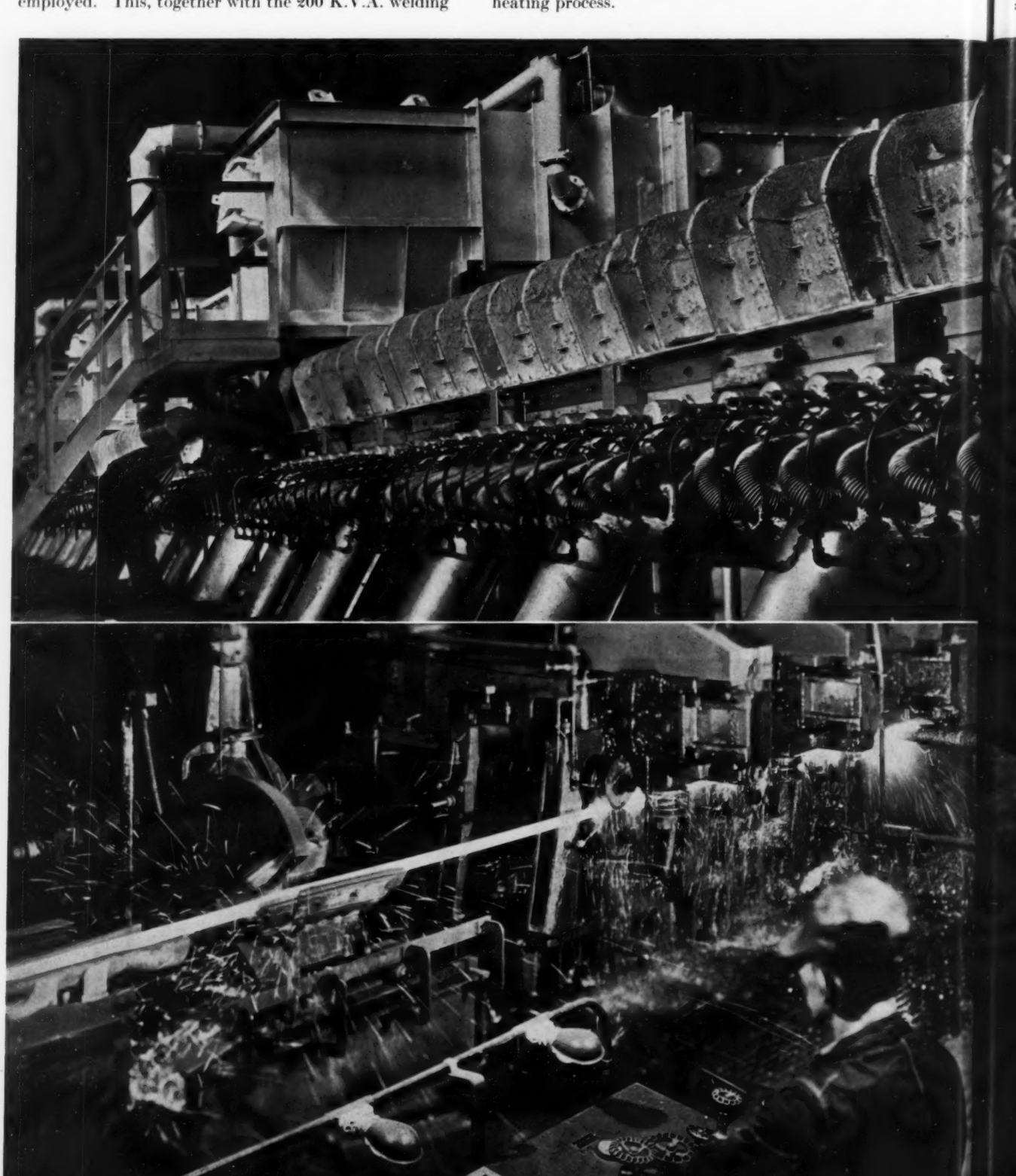
The entire installation is electrically operated, and is controlled from two central points. Machinery on the charging end, including leveller, welder, trimmer and pinch rolls are controlled at that point, while the mill

Three recuperators are installed on the furnace, one for each firing zone. All furnace instruments and controls are grouped on the one central panel board.



and other equipment on the discharge end of the furnace are all operated from a central control table located adjacent to the mill. The accompanying tabulation shows data on the various motors used on the unit. In all, 19 motors, totalling 234.5 connected H.P. are employed. This, together with the 200 K.V.A. welding transformer, represents the total electrical load of the production line proper.

Advantages derived from the installation include reduced costs, lower rejections and higher quality, due to continuous operation and to close control of the heating process.



To the left and below—Subject to the action of 274 gas burners, the strip passes through the furnace, from which it passes through air jets and on into the forming and welding rolls. Cut to exact desired lengths by the travelling hot saw, straightened and cooled, the pipe is then ready for subsequent testing and threading operations.

MOTOR DRIVE DATA

Application	H.P.	R.P.M.	Voltage	Current
Roller leveller	25	400/1600	230	D. C.
Butt welder pushup	5	1200	220	A. C.
Butt welder flash trimmer	10	870	220	A. C.
Furnace roller conveyor	3	450/1800	230	D. C.
Combustion air blower	60	1750	220	A. C.
Dilution air blowers (3) (3)	7½	1750	220	A. C.
Blower for edge of skelp	30	3450	220	A. C.
Welding mill motor	15	400/1600	230	D. C.
Automatic hot saw	5	3450	220	A. C.
Conveyor, hot saw to small rack	3½	400/1600	230	D. C.
Small cooling rack	3½	400/1600	230	D. C.
Conveyor to descaler	3	650/1950	230	D. C.
Descaler	15	400/1600	230	D. C.
Conveyor to large rack	3½	400/1600	230	D. C.
Large cooling rack	7½	600/1800	230	D. C.
Straightener	25	400/1600	230	D. C.
Conveyor	3	1150	230	D. C.
Total, 19 motors	234.5			

Cost of WELDIN *and* WELDED PRODUCTS

By E. W. P. SMITH, Cons. Enginee

LINCOLN ELECTRIC CO.

CLEVELAND, OHIO

▲ COST of a product—and that includes not only the expenditure of time, money and materials, but also must include the service or performance of the product—is most important, because it involves each and every process and aim of manufacture.

These processes are (1) preparation, (2) welding, and (3) final or finishing treatment. Preparation of a study of type of joints, machining of the joints, shaping of the parts and sub-assembly. These are operations which must precede the welding. Welding involves labor, electrode and power. Labor cost is affected by the operating factor, which in turn is affected by positioning and the use of jigs and fixtures. Electrodes require a study of size and type or kind most suitable—size. Power involves not only the characteristics of the supply generator, a matter of efficiency of power conversion, but also the size of machine, which in turn is closely related to the required production. Following the welding is the final or finishing process which may be some simple item such as a nameplate and painting or more elaborate as stress relieving or heat treatment.

Each of the above operations has its effect on the cost, and they must be so combined as to result in the lowest cost of the product.

A study, therefore, of these factors and their relationship results in some startling and revealing facts.

TYPE OF JOINT

The determination of the type of joint is dependent upon a number of items. (1) Load—(2) How the load is applied, that is steady, impact, endurance and (3) (3) Cost of preparation. The load is a matter which concerns design, but the subject under discussion is cost, therefore, it may be assumed that the type of joint has been determined from load basis or requirements.

As an example assume a butt joint is required. There are several types of butt joints. The plain butt—preparation of which is simple—straight cuts to dimension, with opening between plates depending upon plate thickness. (See Figure 1.)

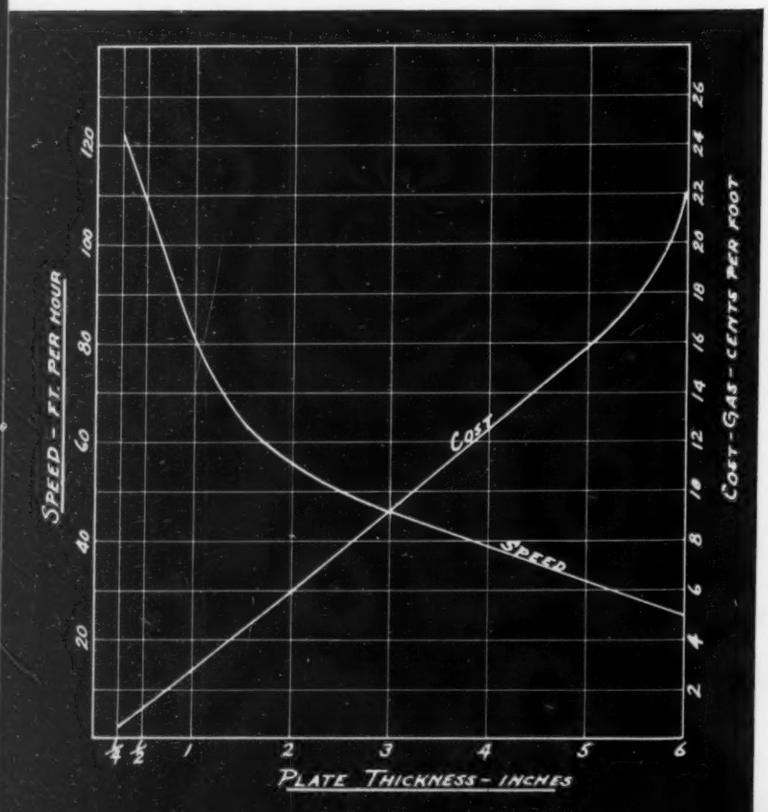
The single vee joint—preparation of this costs more than the plain butt joint and more electrode is required. (See Figure 2.)

The double vee joint—Cost of machining is higher than single vee but it requires only half the amount of electrode for the same plate thickness. The cost of machining and the cost of welding must both be studied and the joint selected on the basis of lowest cost. As an example, in a given plant the cost per pound of deposited metal is known and the cost of machining per foot is known. A combination of these two resulting in lowest cost is selected. This can be rather easily done when basic cost figures are known. (See Figure 3.)

Next in matter of preparation is machining of parts. A study of this in relation to welding will often indicate changes in either welding or machining or both and consequently a cost reduction. Take, for example, the type of scarf—Single Vee—Double Vee—Single U—Double U. There is also the matter of shaping or forming the parts. Is it lower in cost to bend a plate rather than weld two plates? Shall a combination of welding and forming be used, or will plates cut to size and welded, produce lowest coat? Can combinations of several shaped parts be used?

These shapes are not only bent and formed but may also be cut by gas or by machine to usual and unusual shapes. It is interesting to note that up to 5″ thick plate (incl.) with oxygen at $1.00 and acetylene $2.00 per 100 cu. ft. the cost for gas per 100 square inches cut is about 25 cents. The speed of cutting increases

FIGURE 4—Relationship of speed and cost of welding to plate thickness.



Presented before the A. S. M. E. at St. Louis, Mo., June 20-24, 1938

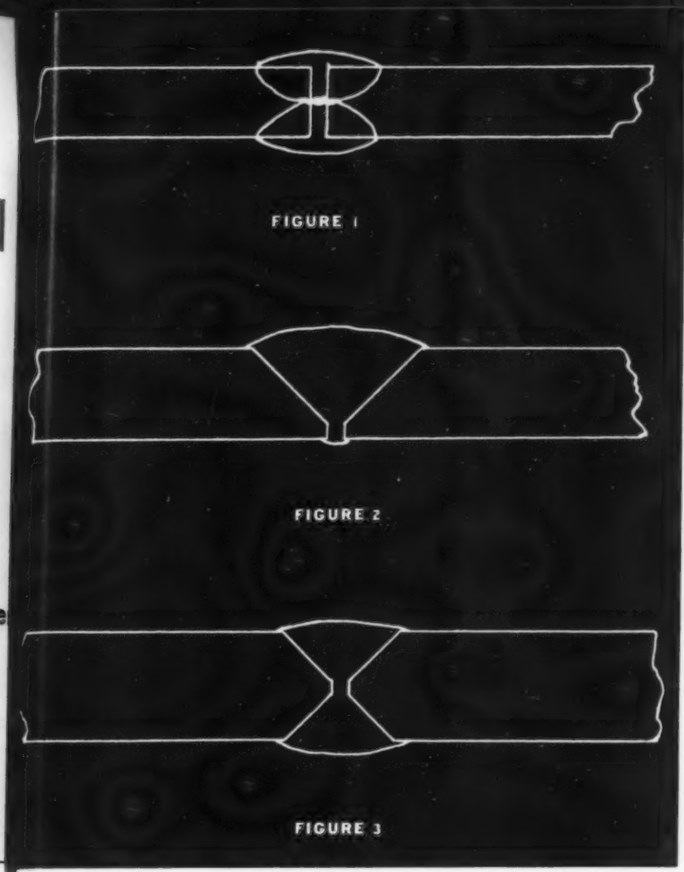


FIGURE 1

FIGURE 2

FIGURE 3

rapidly as thickness of plate is reduced so there is no easily remembered relation throughout this range of plate thickness. (See Figure 4.)

The data given above are for no fatigue—no set up. By careful use the cost of gas per foot is not materially changed by the operating factor, but labor cost is. The speed and labor, with or without overhead may, therefore, be converted to cost per foot cut—and a suitable curve plotted. Assume operator is paid $1.00 per hour and operation factor is 50 per cent, then cost per cut can be readily calculated by adding to gas cost per foot of cut, the labor cost per foot cut. The sum of the two being the cost per foot.

Next is the matter of sub-assemblies. Obviously, only general statements can be made. But a study of assemblies and sub-assemblies, the ease of handling, accessibility of welds, are all factors to be considered, and welding permits these sub-assemblies and assemblies to be so easily made.

The preparation of these for welding involves determination of type of joint, machining of joint, shaping and cutting of the parts and sub-assemblies, and their effect on welding cost.

Welding cost is made up of three general parts—(1) labor, (2) electrode, (3) power.

Labor costs depend largely on the operating factor and the speed of welding.

Assume a labor rate of $1.00 per hour, and an arc speed of 50 feet per hour. (Arc speed is the rate of travel of the arc and may be expressed in inches per minute or feet per hour.)

Then for different operating factors (operating factor is percent of total time the arc is in operation):—see Figure 5 and Table 1.

It is obvious from inspection of this curve that the greatest cost reduction can be made by increasing the operating factor, that is to keep the operating factor in the higher brackets. One method of doing this is by use of proper jigs and fixtures and proper set up. Suppose it takes an operator two minutes actually to weld a job and two minutes or slightly less to set it up. Four minutes per part or fifteen per hour.

If however, a helper is provided and another jig, then the helper can set up while operator is welding and production is 30 parts per hour at a lower cost per part.

15 per Hour Takes	30 per Hour Takes
1 Jig	2 Jigs
1 Welder	1 Welder
1 Operator	1 Helper
(See Figure 6)	1 Operator

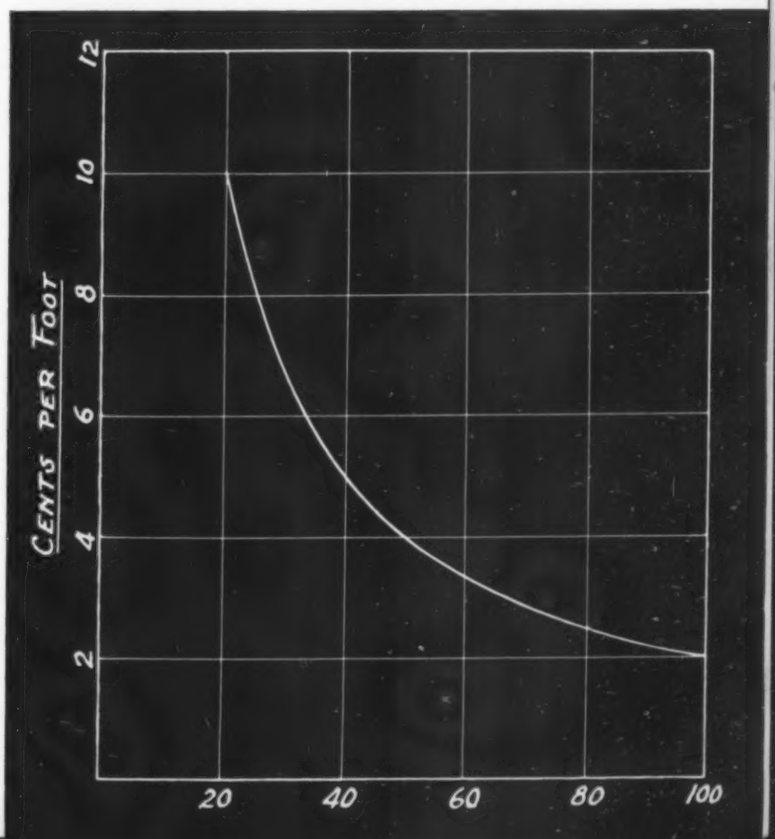
The cost reduction is obvious since the second fifteen are obtained at a cost of 1 jig and 1 helper.

Another factor in reducing labor costs is matter of

TABLE I

Operating Factor	Production per Hour (Ft. per Hr.)	Cost per Foot
20%	10	$ .10
40%	20	.05
60%	30	.0333
80%	40	.025
100%	50	.02

FIGURE 5—Curve showing variation of cost of welding with changing operating factor. (Also see Table I.)



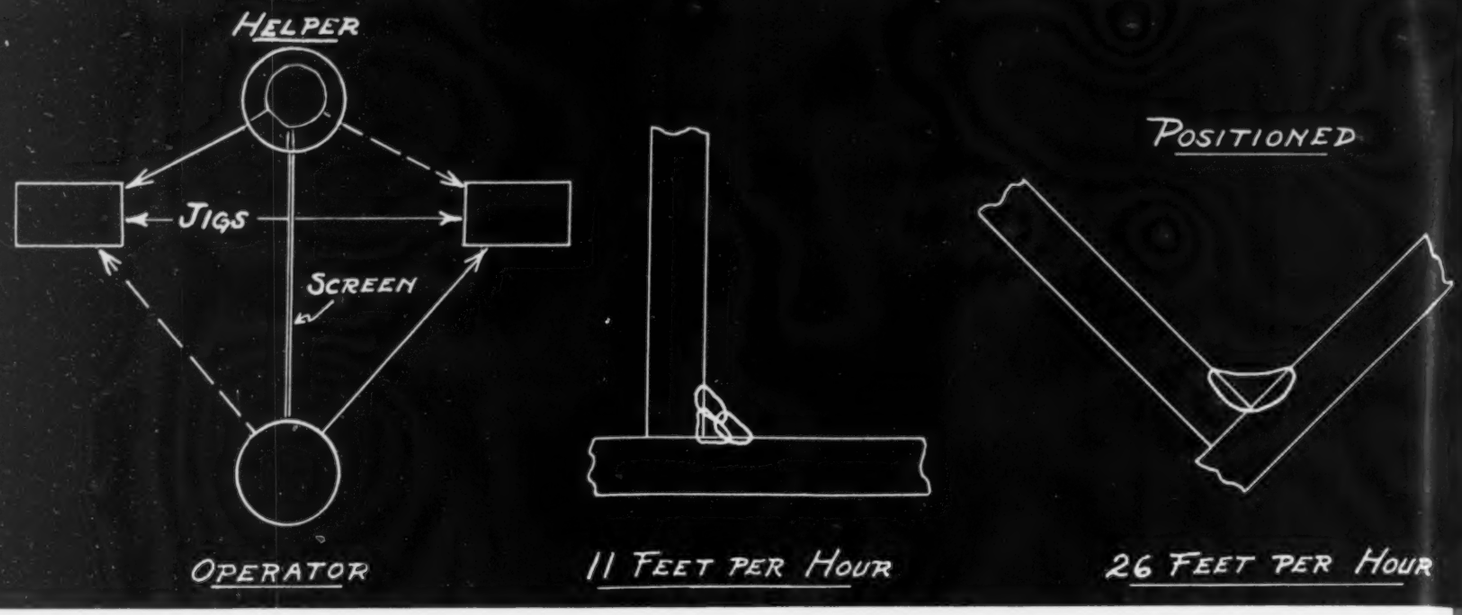


FIGURE 6—The use of a helper and an additional jig doubles production.

FIGURE 7—Proper positioning of the work results in still further increase in production.

positioning so it is convenient and easy for the operator to weld. This aid to convenience will be very helpful in cost reduction.

In addition, the matter of so placing the part that the operator can always weld down will result in considerable increase in speed of welding and less fatigue of operator. For example, a ½″ fillet weld would be at 11 ft. per four arc speed. If it were positioned the arc speed would be 26 feet per hour—the cost reduction is apparent. (See Figure 7.)

For reduction of costs due to labor, a high operating factor is necessary which can be obtained by proper use of jigs and fixtures. Speed may be increased by proper positioning so as to make it easy for the operator to work.

These labor factors of cost may be applied to a great many fabrication processes but are particularly controllable when applied to welded fabrication.

The cost due to the electrode is an important factor, and note the statement, not the cost per pound of the electrode but the cost due to use of electrode. The size, the quality of deposit, the physical characteristics of the joint, are all items dependent upon the electrode.

The matter of size of the electrode used is a considerable factor of cost of deposited metal and joint. As a basis of discussion, assume that only the size is changed. The deposition efficiency, that is ratio of deposited metal to total electrode purchased, kind of joint, and all other items except electrode size are kept fixed.

As an example calculate the cost per pound of deposited metal on the following basis:

Labor at $1.00 per hour	Operating Factor	50%
Power at .02 per kwh.	Overhead	100%
Electrode as indicated	Deposition Eff.	66 2/3%

TABLE II

EFFECT OF ELECTRODE SIZE ON COST OF DEPOSITED METAL

Electrode Size	1/8	5/32	3/16	1/4	5/16	3/8
Amperes	110	130	150	250	325	425
Arc Volts	24	25	26	30	34	38
Kw. at Arc	2.64	3.25	3.9	7.5	11.1	16.1
Consumption Rate Lbs. per Hour	2.6	3.3	3.95	7.5	10.7	16.2
Deposit, Lbs. per Hour (50% Operat. Factor)	.87	1.1	1.32	2.5	3.57	5.4
Eff. of Set (%)	47	50	51	55	59	59
Kw. Input	5.6	6.5	7.65	13.65	18.8	27.3
Interruptions per Lb. Consumed	18	12	8	5	3	2

COST PER POUND DEPOSITED

Labor	$1.150	$ .909	$ .758	$ .400	$ .280	$ .185
Overhead	1.150	.909	.758	.400	.280	.185
Power	.064	.059	.058	.055	.053	.051
Electrode	.150	.135	.127	.127	.127	.127
Cost of Interruption	.050	.033	.022	.014	.008	.005
	$2.564	$2 045	$1.723	$ .996	$ .748	$ .553

(See Figure 8.)

Note that the use of ¼″ electrode in place of 3/16 means a cost reduction of 42 per cent, $\frac{.995}{1.717} = 58$ per cent, and a study of the curve in Figure 8 shows the economy and cost reduction to be obtained by use of proper size electrode—that is, to obtain the lowest cost, the largest size electrode which can be used is the most efficient.

Further reasons for the use of a large electrode is that

tendency to distortion is less with fewer number of passes and large electrodes permit fewer passes. Ductility is higher with fewer number of passes. A reduction in cost, an improvement in quality, results from the use of large electrodes.

Another item to consider in relation to costs of welding is the performance of the electrode. The cost per foot or per pound of deposited metal, not the cost per pound of electrode purchased, is the important item of cost in so far as electrode is concerned. Perhaps it might be said that deposition efficiency and speed are the determining factors because it must be true that the physical performances for the electrodes to be compared are the same or nearly so.

An elementary illustration of this in reference to speed only will be illuminating—

100 Feet of Welding

Arc Speed (Ft. per Hr.)	20	25	30	40
Arc Time	5	4	3.3	2.5
Set Up Time Hours	2	2	2	2
Total Time	7	6	5.3	4.5

If each hour cost $2.00 then the following results are obtained:

Time—(Hrs.)	7	6	5.3	4.5
Arc Speed (Ft./Hr.)	20	25	30	40
Cost	$14.00	$12.00	$10.60	$9.00
Cost Reduction		$2.00	$3.40	$5.00
Increase in Production		17%	32%	55%

Based on 7 hours as standard.

Note that set up time is not changed, but because of arc speed increase there is a marked increase in production with no increase in equipment or floor space.

For general set up some curves may be used. (See Figure 9.)

While this may appear rather elementary it is quite frequently overlooked in actual practice.

A combination of the consumption rate and speed,

FIGURE 8—Cost of welding drops rapidly with increased electrode size.

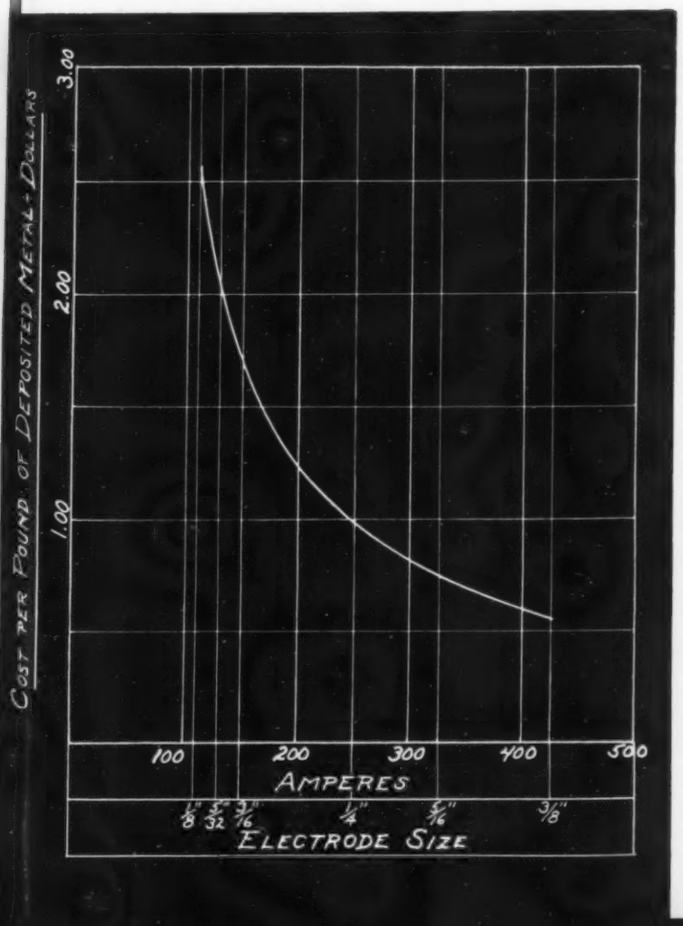
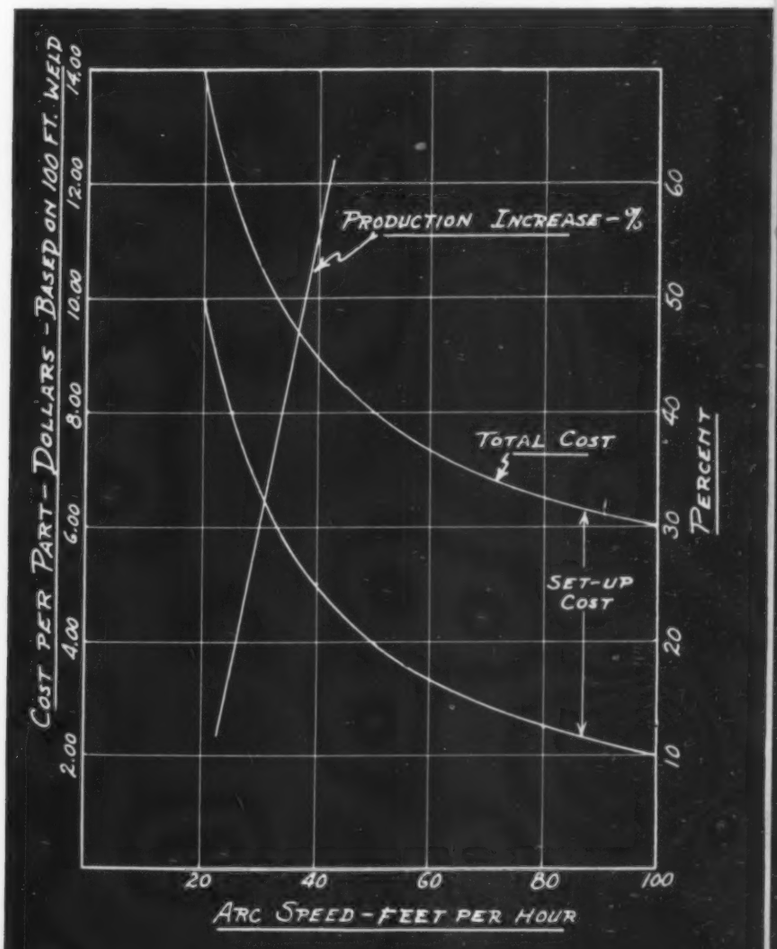


FIGURE 9—Curves may be set up showing fluctuation of production and cost with varying arc speed.

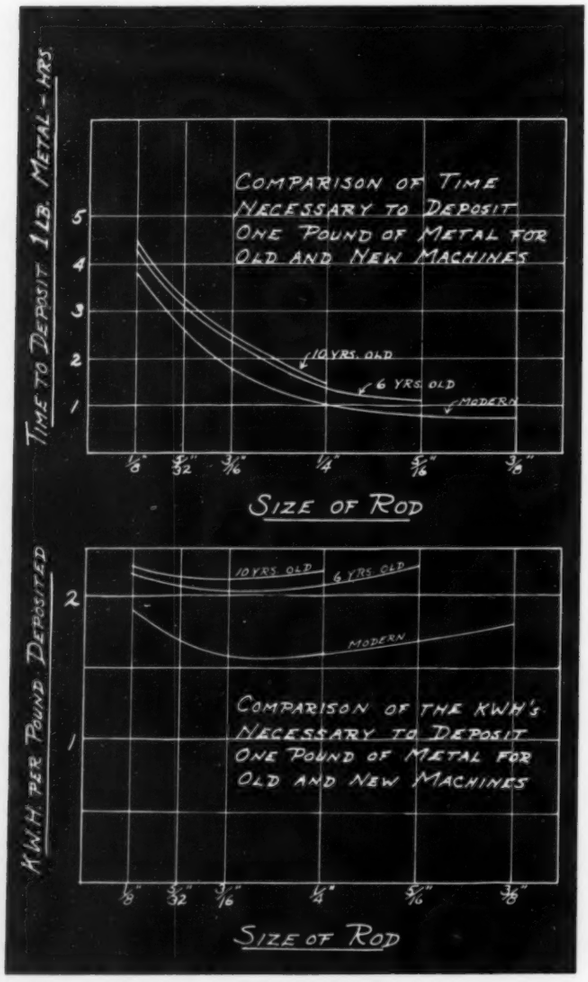


(data taken from actual test), shows some interesting commercial results.

Take for comparison two electrodes of the following characteristics and test results:

Size	¼	¼
Amperes	340	340
Volts	34	34
Arc Kw.	11.56	11.56
Eff. Generator	59.5%	59.5%
Coating Per Cent in 14"	22.2	20.1
Wt. Electrode Used	1.60 lbs.	1.56
Wt. Stub Ends	.231	.386
Electrode Used	1.369	1.174
Wt. Plate + Deposit	15.860 lbs.	15.790
Wt. Plate	14.915	14.940
Wt. Deposit	.945	.850
Time	7.867 min.	5.916
Percent Loss	30.94	27.55

FIGURE 10—Test curves showing time and power requirements to deposit one pound of metal on old and new welding machines.



Dep. Lbs. Per Hr.

$$\left(\frac{.945}{7.867} \times 60\right) = 7.22 \qquad \left(\frac{.850}{5.916} \times 60\right) = 8.62$$

The welding metal deposited was comparable:

Yield Point	51,100	53,100
Tensile	64,800	65,100
Elongation 2"	19.9	23.1

It is more or less obvious that the higher rate of deposition is preferred but the full effect of this on the cost is not readily realized unless the cost is calculated on the basis of a certain amount of metal such as 10,000 lbs.

Labor	$1.00 per hour
Power	.02 per kwh.
Electrode	.085 per lb.
Operation Factor	50%

Then time in hours to deposit:

$$10{,}000 \text{ lbs.} = \frac{10{,}000}{7.22} \times .50 = 2770$$

$$\frac{10{,}000}{8.62} \times .50 = 2320$$

Kwh. to deposit 1 lb. is:

$$\frac{11.56}{.595} \times 7.22 = 2.69$$

$$\frac{11.56}{.596} \times 8.62 = 2.25$$

Add 10 per cent to results to take account of idling losses.

Power for 10,000 lbs. = 29,600 kwh. 24,800 kwh.

Electrode required equals:

$$\frac{10{,}000}{.6906} = 14{,}480 \text{ lbs.} \qquad \frac{10{,}000}{.7245} = 13{,}800 \text{ lbs.}$$

Summation:

Hours to deposit 10,000	2,770	2,320
Kwh.	29,600	24,800
Electrode Lbs.	14,480	13,800
COSTS		
Labor	$2770.00	$2320.00
Power	592.00	496.00
Material	1231.00	1175.00
	$4593.00	$3991.00
Cost	$3991.00	
Reduction	602.00	

$\frac{\$\ 602.00}{10{,}000}$ = 6 cents per pound deposited cost reduction.

Six cents per lb. deposited is about 4¼ cents per lb. purchased, which is a very considerable item—50 per cent of the purchase price of electrode.

POWER

The deposition of metal involves use of power and it is with this item we are next concerned. Power is supplied by welding generators, driven usually by an electric motor and this kind of set will be used in illustrating power costs. In selecting a generator, in order to keep costs down, the most modern generators available should be used. The curves show test results

made on generators of different sizes, and the results are proof positive of the economy of using a modern generator. (See Figure 10.)

As demonstration of the above general statement the following actual test data:

Length Weld 896 Inches	40 Volt Gen. New	25 Volt Gen. Old
Actual welding time—min.	126.3	177.6
Kwh. input per seam.....	22.3	24.8
Power cost 100 inches weld	$ .020	$ .022
Inches weld per rod.....	7.7	6.6

Next is the selection of the size of the generator. To do this it is necessary to know the application, that is the size and type of joints, plate thicknesses, not only as to dimension but also the percentage of total shop production for each. These plate thicknesses can be expressed in terms of welding as arc amperes.

It is obvious that generators of different sizes have different efficiency curves and that these curves cross. (See Figure 11.)

If the greater part of the work is done to right of K, then (B) or larger size is used as it is the most efficient. It is well to recall here that large electrodes result in reduced cost and larger electrodes require higher currents which are obtained at higher efficiencies.

In calculating power costs, efficiency is the governing item and the larger electrodes operating on a larger machine result in operation at a point of high efficiency.

It is necessary, however, that this efficiency be that at the arc voltage and amperes.

Usually efficiencies are given at 40 volts.

As for example:

Amps.....	120	200	300	400	500
Eff. 40 V.....	60%	64%	65%	64%	61%
Usual Arc Volts..	25	28	32	37	40

If the efficiencies are known at 25 volts as well then an operating efficiency curve may be plotted. (See Figure 12.)

Another curve of interest and use is a curve on deposition.

Assuming ¾ deposition factor
100 per cent operating factor
Then from Table II

Amperes.....	110	130	150	250	325	425
Deposit lbs. per hr. (100 per cent operating Factor).....	1.74	2.2	2.64	5	7.14	10.8

(See Figure 13)

Some very interesting and useful facts can be obtained by combining this last curve and the tabulation given.

If the 25 volt efficiencies are not known the efficiencies at arc voltage may be calculated approximately as follows:

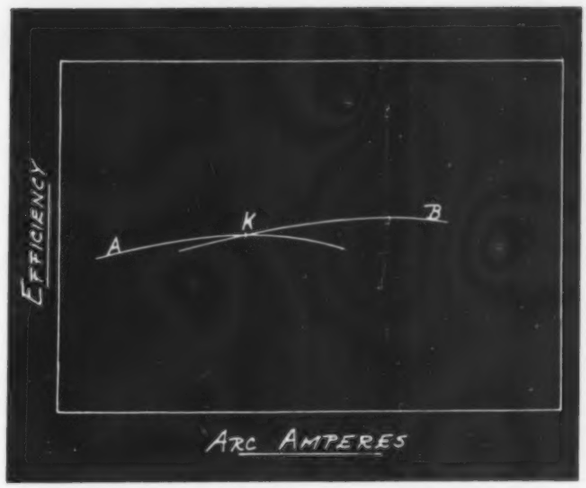


FIGURE 11—The different efficiency curves shown by generators of different size indicate the importance of selection of proper size.

Amperes.....	120	200	300	400	500
Kw. Output at 40 V....	4.8	8	12	16	20
Eff. 40 V. (%).....	60	64	65	64	61
Kw. Input at 40 V.....	8.0	12.5	18.4	25	32.8
Arc Volts.....	25	28	32	37	40
(40 — Arc Volts)					
1000					
x Amps.....	1.8	2.4	2.4	1.2	.....
Kw. Input at Arc Volts.	6.2	10.1	16	23.8	32.8

The kw. Input at arc voltage is the desired factor and there is no need to calculate efficiency in percent.

FIGURE 12—Operating efficiency curve may be developed from efficiency curves at upper and lower voltage limits.

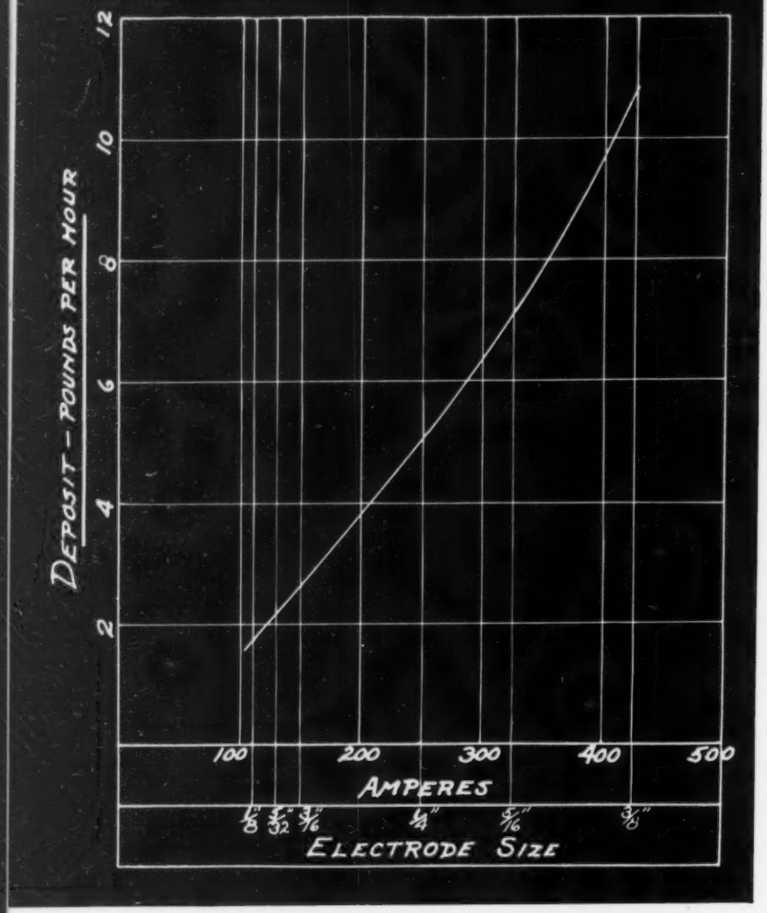


FIGURE 13—Curve shows rate of metal deposition as related to amperes and electrode size.

Amperes	120	200	300	400
Kw. Input (Arc Volts)	6.2	10.1	16	23.8
Lbs. deposited	2	3.8	6.4	9.8
Lbs. purchased	3	5.7	9.6	14.7
Kwh./lb. purchased	2.07	1.78	1.68	1.62
Cost Power (Cents at 2¢ Kwh.)	12.4	20.2	32	47.6
Cost Electrode (8½¢/lb.)	25.5	48.5	81.5	24.8
Total Cost (Elec. and Power)	37.9	68.7	113.5	172.4

If the costs are plotted against amperes (arc) then the curves shown on Figure 14 are obtained. The labor charge is the hourly labor rate divided by the operating factor, or it may be labor charge plus overhead, so that the total obtained is the cost per hour of operation. These are added to the curves for electrode and power cost as shown.

Then for any *arc ampere*, as for example 250 ampere with labor at 71.00 per hour, operating factor 50 per cent, the labor item = $2.00 (1.00 ÷ 50 per cent). For an *arc* speed of 20 feet per hour the cost is obtained by starting at 250 amperes—going to the labor items marked $2.00, horizontally to the arc speed curve, and down to cost per foot, 14.5 cents. Position, type of joint, deposition efficiency, all govern speed. If, therefore, the total cost of operation is divided by the speed all factors are accounted for.

For individual use in specific cases, this can be further simplified. Suppose power and electrode figures are as given above 2 cents per kwh. and 8½ cents per lb., labor is $1.00 per hour and operating factor is 66-2/3 per cent. Labor item is then $1.50. Our tabulation then becomes:

Amperes	120	200	300	400
Elec. + Power Cost	37.9	68.7	113.5	172.4
Labor Item	150	150	150	150
Total	187.9	218.7	263.5	322.4

Instead of plotting as in previous curve, the amperes and the cost scale are plotted together and we have one scale—amperes to get directly the cost per foot. (See Figure 15.)

These three items—labor, electrode, power, are the basic ones of welding costs.

But even these are influenced by and may influence the final or finishing treatment. Such treatment may be as simple as painting or nameplating. Painting involves accessibility, which may be a matter of preparation.

Stress relieving and/or heat treatment may mean special consideration in preparation and handling; question of collapse or deformation when metal is soft; how to support and provision for escape of gases. There must be no completely enclosed parts, otherwise the expansion of the air would cause deformations. All of these must be given careful thought and their interrelation thoroughly studied.

This final treatment or finishing process is related to preparation, the method of handling of joints or subassemblies and these in turn effect labor, electrode and material costs.

Welding costs are reduced by (1) use of larger machines which are more efficient than smaller ones, (2) by use of large electrodes which deposit metal of high ductility. This large electrode results in less tendency toward distortion. The use of large generators and large electrodes produces, therefore, welded construction of improved quality and at low costs. And when quality goes up and cost goes down can more be required of a process? Arc welding does just that.

FIGURE 14—Chart showing cost of welding under various conditions.

FIGURE 15—Chart showing cost of welding under specific conditions.

FIG. 14

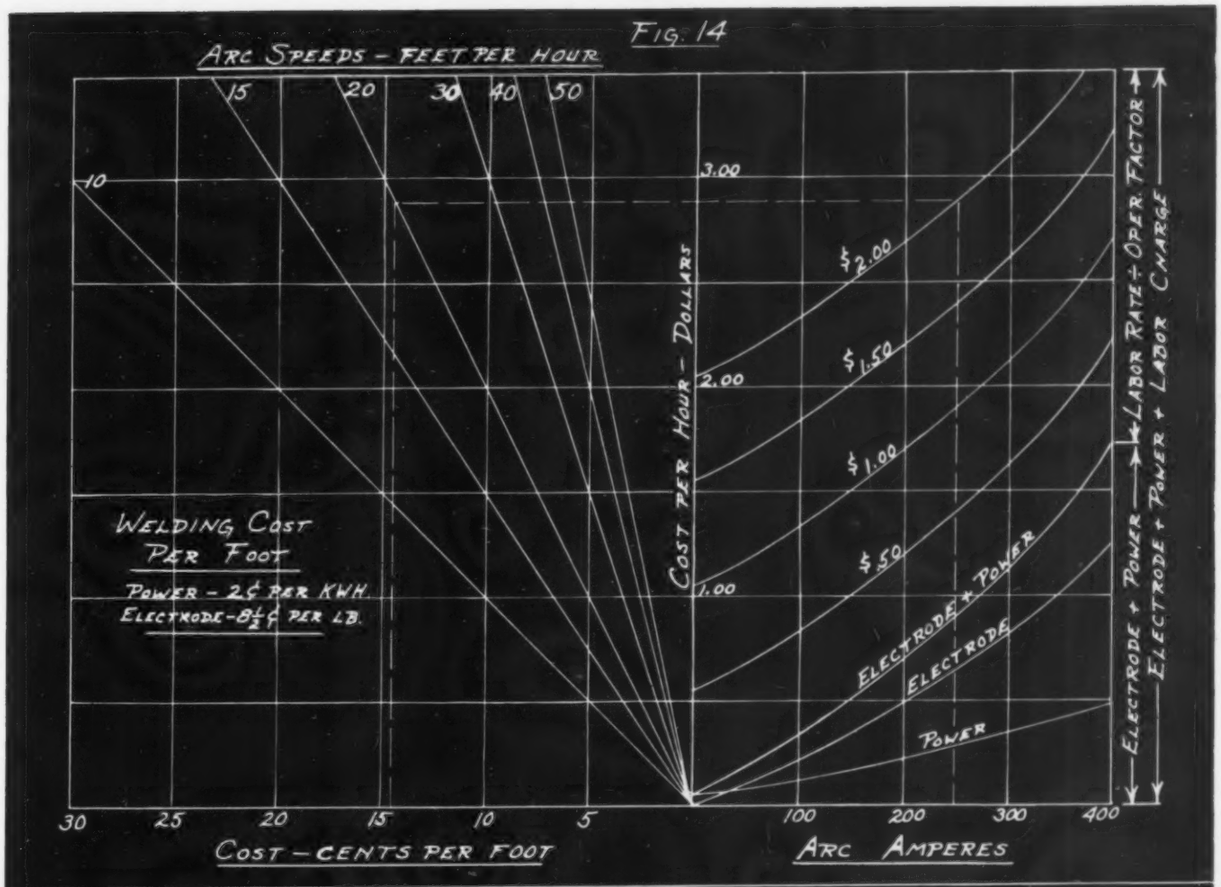
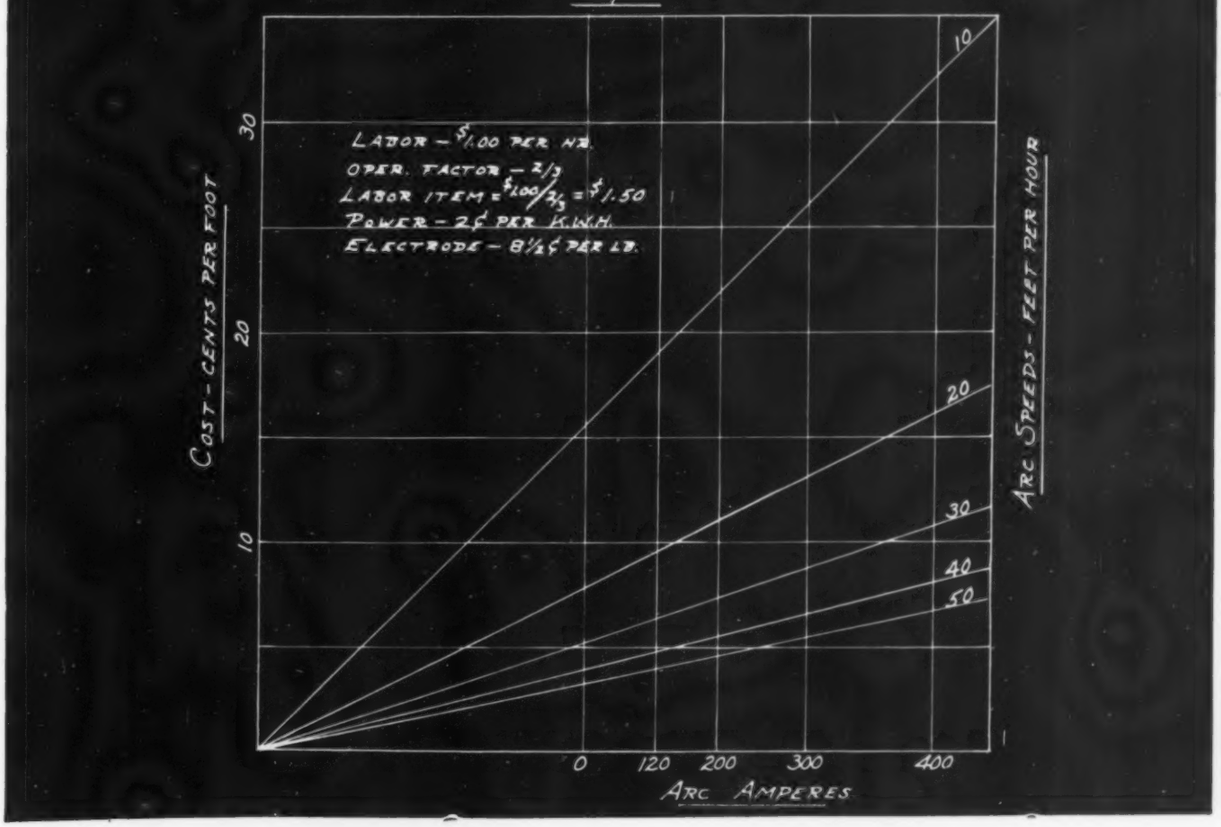

ARC SPEEDS - FEET PER HOUR
15
20
30
40
50
10
3.00
2.00
1.00
COST PER HOUR - DOLLARS
$2.00
$1.50
$1.00
$.50
ELECTRODE + POWER
ELECTRODE
POWER
ELECTRODE + POWER ÷ LABOR RATE ÷ OPER. FACTOR
ELECTRODE + POWER + LABOR CHARGE
WELDING COST PER FOOT
POWER - 2¢ PER KW.H.
ELECTRODE - 8½¢ PER LB.
30
25
20
15
10
5
COST - CENTS PER FOOT
100
200
300
400
ARC AMPERES

FIG. 15


LABOR - $1.00 PER HR.
OPER. FACTOR - 2/3
LABOR ITEM = $1.00/2/3 = $1.50
POWER - 2¢ PER K.W.H.
ELECTRODE - 8½¢ PER LB.
COST - CENTS PER FOOT
30
20
10
10
20
30
40
50
ARC SPEEDS - FEET PER HOUR
0
120
200
300
400
ARC AMPERES

D. C. Power Supply

FOR STEEL MILL APPLICATIONS

By W. B. SNYDER, Industrial Dept. *and*
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SCHENECTADY, N. Y.

Presented before the A. I. & S. E.
Chicago District Section
November 16, 1937

▲ THERE are few processes in the production of steel where direct current power is not used. The ability of the direct current mill auxiliary motor to stand up under abuse which will cause any other type of motor to fail has made its application universal on heavy duty auxiliary drives. The flexibility and preciseness of control obtainable with the direct current motor has made possible the development of the modern hot and cold strip mills. Economy, quickness of response, and freedom from costly shutdowns have made the direct current reversing motor pre-eminent as the drive for blooming and slabbing mills. For these reasons the Steel Industry is perhaps the largest user of direct current power.

Practically all of the direct current power used in steel plants is initially generated as a-c power, and thus a-c to d-c power conversion plays an important part in steel mill activities. It may be well, therefore, to consider the requirements of the major forms of direct current applications and the types of conversion equipment available to meet these requirements.

CLASSES OF DIRECT CURRENT SYSTEMS

Direct current power systems in steel mills fall roughly into three classes: (1), the 250 volt plant distribution system for supplying cranes and auxiliary drives; (2), the system supplying power to a mill with a large number of direct current motors, such as a continuous hot strip mill, and (3), the system which supplies power to one or more reversing motors, such as those which drive blooming or slabbing mills.

COMMON REQUIREMENTS

These systems have several requirements in common The first is, of course, reliability, due to the serious consequences of power failure in rolling mill operations. Efficiency is also important, but it is secondary to reliability, since power cost is only a small item in the cost of steel production. Formerly it was extremely desirable that conversion units supply a large amount of leading kva to the a-c system, but this requirement is becoming of decreasing importance, due to the large amount of synchronous apparatus (chiefly in motor-generator sets) now installed in steel plants.

250-VOLT DISTRIBUTION SYSTEM

The 250 volt system is fed from a large number of conversion units disposed at load centers throughout the plant. Thus, these units must parallel properly and maintain good voltage at the motors under widely varying conditions of load distribution. There is a growing trend toward the application of voltage regulators to the units supplying the 250 volt system, in order to insure good voltage and load distribution, and thus it is increasingly important that the conversion units be adaptable to regulator control.

It is the general practice to take conversion units off the line during light load conditions. This is particularly true of those associated with the individual mills, which are shut down when the mill is not running. In spite of this there are periods during which the units are lightly loaded, and thus high part load efficiency is desirable.

It is desirable to provide automatic control for those units supplying the general plant distribution system. Such control will start the machines and put them on the line when load conditions demand it, and shut them down during periods of light load. Automatic control is however, not usually justified for those units which supply individual mills, as these are located in the motor room with the mill drives and no additional operators are required for them.

600-VOLT CONTINUOUS MILL SYSTEM

The 600 volt continuous mill systems have highly concentrated loads supplied from a number of units located in one motor room. An installed capacity of 18,000 kw is not uncommon. Each system operates entirely independently, with no interconnections with other systems.

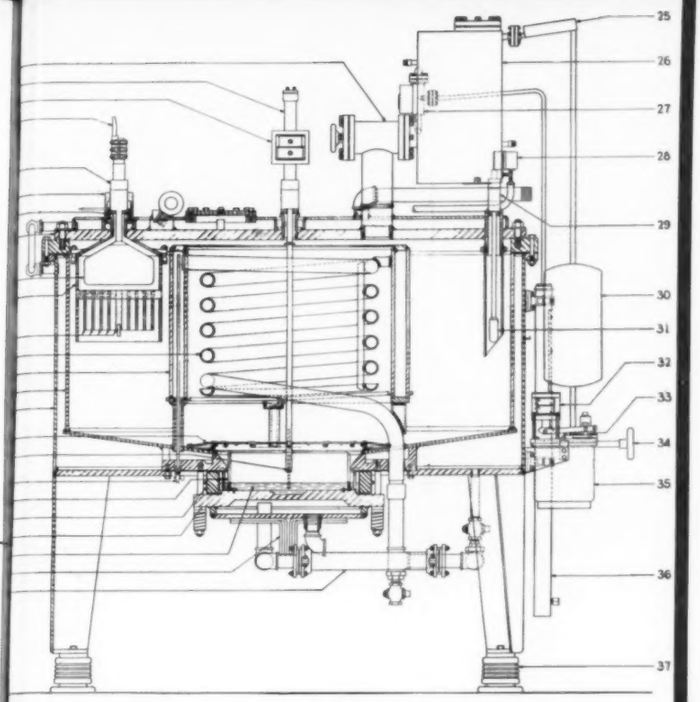


FIGURE 1—Cross-section of multiple anode tank mercury arc rectifier. Modern metal tank rectifiers have been largely of this construction.

Continuous mills are usually started by connecting the motors to the direct current bus with no voltage on the system, and then smoothly raising the bus voltage to the normal value. This dispenses with magnetic starting equipment, which is extremely expensive and bulky for the larger motors. Thus, the conversion units of the 600 volt system must be capable of voltage adjustment for starting purposes. Some installations also require a range of voltage of, say, from 450 to 600 volts, to obtain a range of mill speed beyond that economically practicable by field control on the direct current motors. On such systems, the conversion units must be capable of operating for long periods of time at reduced voltage.

The high speeds of modern continuous mills require driving motors with stable speed characteristics. This, in turn, requires constant bus voltage, so that the conversion units must be adaptable to voltage regulator control.

Regenerative braking of the motors driving a continuous mill is of some advantage, although the motors of a few of the later mills are arranged for individual dynamic braking. Regenerative braking requires in addition to d-c voltage control down to zero, that the conversion units be capable of passing power in either direction.

REVERSING MILL SYSTEM

The direct current motors on reversing mills must reverse from full speed to full speed with extreme rapidity, must make several reversals per minute, and must be able to carry extremely high peak loads. On the larger motors, such operation is possible only with adjustable voltage control. Other types of control may be used on smaller motors of, say, 200 or 300 hp capacity, but only at the sacrifice of operating efficiency.

The conversion units for reversing mill systems must, therefore, be capable of smooth and rapid control of voltage from the maximum value in one direction to the maximum in the other direction. Ability to reverse the flow of power is essential, so that the stored energy of the drive may be returned to the a-c system during deceleration. Means of equalizing the peak loads on the a-c system are essential for the larger drives, and sometimes desirable for the smaller ones.

TYPES OF CONVERSION UNITS

Three types of conversion units are commercially available to supply power to these large direct current systems. These are (1) the synchronous converter, (2) the motor-generator set driven by either a synchronous or an induction motor, and (3) the mercury arc rectifier. The characteristics of these machines which affect their suitability for steel mill service are discussed below.

SYNCHRONOUS CONVERTERS

The synchronous converter is an efficient source of direct current power. However, its direct current voltage is a function of the alternating current voltage, and thus voltage fluctuations on the a-c system are reflected directly into the d-c system. This gives rise to troubles such as fluctuations in speed of the direct current motors, unnecessary tripping of direct current undervoltage relays, and difficulties in paralleling with other types of conversion apparatus. The synchronous converter voltage may be varied only by transformer tap changing, which produces rather coarse steps over a limited range, or by means of a booster, which is bulky and expensive. Thus, the converter is essentially a constant voltage machine, not adaptable to regulator control, and difficult to parallel with other forms of conversion apparatus.

The control for the synchronous converter is somewhat complicated, due to the necessity of raising the brushes and establishing proper polarity when starting from the a-c end.

Thus, although the synchronous converter is the least expensive form of conversion apparatus and, within its limitations, a reliable and efficient machine, it is not very well adapted to steel mill requirements. In recent years only a very few synchronous converters have been installed in steel mills.

MOTOR-GENERATOR SET

The motor-generator set is today preeminent in a-c to d-c power conversion for steel mill applications. Its characteristics are excellently suited to the requirements of all three types of systems. The direct current voltage is independent of fluctuations (other than frequency variation) in the a-c system. It is well adapted to regulator control which, of course, will compensate for frequency variation.

The motor-generator set is extremely flexible, as its

direct current voltage may be varied smoothly by simply means from zero to the full value in either direction. The power flow may be reversed by controlling the direct current voltage. Thus the motor-generator set is ideally adapted to Ward-Leonard operation, providing for the direct current motors smooth and rapid acceleration and deceleration, power regeneration, and speed adjustment by voltage control.

Since the volt-ampere characteristics of the direct current generator may be adjusted by series fields good parallel operation is readily obtained between machines of different capacities.

The synchronous motor-generator set is an excellent source of corrective kva for the a-c system, as the motor may readily be designed for leading power factor. For example, a standard 80 per cent power factor motor will deliver about 75 per cent of its rating as corrective kva at no load, and 60 per cent at full load. For systems where the power factor is already high, the unity power factor motor, which will deliver about 25 per cent leading kva at no load, may be used.

For drives such as reversing blooming mills, where load equalization on the a-c system is desirable, the motor-generator set may be provided with a flywheel and be driven by a wound rotor induction motor. By adjusting the secondary resistance of the induction motor, the flywheel may be made to assist in carrying the peak loads, thus greatly reducing the peaks on the a-c system.

MERCURY ARC RECTIFIER

Although the mercury arc rectifier has been in wide use in the railway and electrolytic fields for many years, it is a newcomer to the steel industry. Thus it may be well to go into more detail in regard to the construction and the operating characteristics of this device.

The principle upon which the mercury arc rectifier is based was discovered shortly before 1900 by Cooper Hewitt. Development proceeded rapidly, and by 1905 the glass tube rectifier was available in almost its present form. However, as the size and capacity of the glass tube rectifiers were increased, practical difficulties arose because of the structural limitations of glass, and so engineers both in the United States and Europe began the development of a metal tank mercury arc rectifier. This development was begun as early as 1905, and has been carried on continuously since about that time in Europe, although it was interrupted in this country during the war. Thus, steel tanks were not perfected to such a degree that they were put into commercial use in this country until about twelve years ago, although they have been in commercial use for a slightly longer period in Europe.

Some idea of the extent of rectifier applications will be obtained from the fact that the Company with which the authors are associated alone has 203 units totalling over 386,000 kw installed or on order.* The voltage classifications of these units are shown in the following table:

TABLE I

Voltage Classification	No. of Units	Kw.
250 volts	8	7,245
600 volts	137	294,715
1500 volts	38	40,600
3000 volts	20	44,000
Total	203	386,560

RECTIFIER CONSTRUCTION

Modern metal tank rectifiers have been largely of the multiple anode tank type of construction. However, the single anode tank rectifier has recently been developed. The following discussion will apply to rectifiers manufactured by the General Electric Company, as the authors are naturally more familiar with these types.

Figure 1 shows a cross section of a multiple anode rectifier. This consists primarily of a cylindrical vacuum tank (14), a flat cover plate (8) bolted to the top of the tank, and a cathode plate (21) bolted to the center of the sloping bottom of the tank. There are only four bolted joints on the tank. These are at the contact surfaces between the top plate and the tank, the cathode insulator and the tank, the bottom plate and the cathode insulator, and underneath the cap over the starting anode. These are made vacuum tight by means of enameled aluminum wire gaskets.

The tank, cover, and cathode plate are water jacketed, and an internal cooling cylinder (13) and cooling coil (12) are provided to remove the heat generated by the arc. The cooling water is treated to inhibit corrosion, and is circulated by a motor driven pump through the rectifier and an external heat exchanger, where the heat of the arc is removed by tap water. As optimum performance of the rectifier is obtained only within a rather narrow temperature range, the tap water circulation is thermostatically controlled, and the heat exchanger is equipped with electric heaters for maintaining temperature during periods of extremely light load.

The cover plate supports the main anodes (9), the excitation anodes (31) and the starting anode (17). The electrical connections to these anodes are introduced through molded Mycalex seal assemblies, which are welded to the cover plate. The main anodes are of graphite, supported on copper studs. They may be provided with grids for voltage or current control. The starting anode is operated by means of a solenoid (3).

The cathode consists of a pool of mercury insulated from the tank by a steel ring (20) coated with vitreous enamel. This enamel is protected from the heat of the arc by two cylindrical quartz rings (19).

A high degree of vacuum is maintained in the tank by a motor driven rotary vacuum pump (35) and a mercury condensation pump (26). The tank is provided with a McLeod gage (36), and with a vacuum regulator

*As of June 1, 1938.

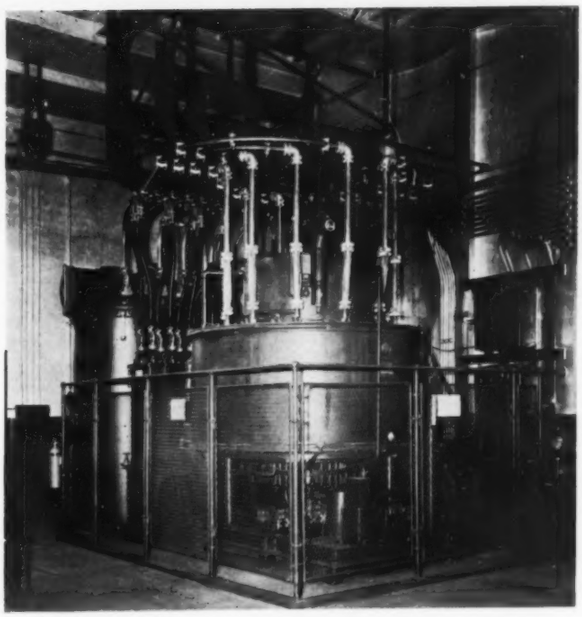


FIGURE 2—A multiple anode tank rectifier of 3,000 kw, 625 volts capacity. Such units are available in a wide range of standard sizes.

for removing the rectifier from the line in case the vacuum should become dangerously low.

Since the rectifier tank is practically at positive line potential, the whole structure is mounted on insulators (37). The cooling water piping is insulated by sections of Formica tubing.

The single anode tank rectifier consists of a number of cylindrical steel tanks, each having one anode in the top plate and a cathode pool of mercury in the bottom. The tanks are provided with common cooling and evacuating systems. Since in the single anode tank rectifier, the arc is maintained only during a half cycle, each tank is provided with an igniter which initiates a cathode spot on the surface of the mercury pool and starts the main arc at the proper instant in the cycle. The single anode tank requires no cathode insulation. The construction of anodes and seals, and of the cooling and evacuating systems, is similar to that of the multiple anode tank rectifier.

The single anode tank rectifier has a lower arc loss, and therefore better efficiency than the multiple anode type, and has the further advantage that the tanks may be made interchangeable, so that if one fails it may readily be replaced by a spare tank.

Figures 2 and 3 are photographs of multiple anode tank and single anode tank rectifiers, respectively.

THEORY OF OPERATION

The processes taking place within the rectifier during operation may be described under two heads, namely, the electronic action and the thermal action. Figure 4 shows the electronic action of a multiple anode tank rectifier.

The rectifier may be considered to be simply a synchronous switch with anodes for segments and the arc from anode to cathode acting as a moving blade. The anodes carry current successively as the arc sweeps around and the rectifying action is due to the fact that a normal anode will permit current to flow only from anode to cathode and not in the reverse direction. The arc is started at the cathode by means of the starting anode which has a rod that is dipped down into the mercury pool. When the rod is removed from the mercury an electric circuit is broken striking an arc and establishing a cathode spot on the surface of the mercury. Electrons are emitted from the cathode spot into the space above where they ionize the mercury

FIGURE 3—The single anode tank rectifier has a lower arc loss than the multiple anode type. Illustrated below is one of 1000 kw, 250 volt capacity.

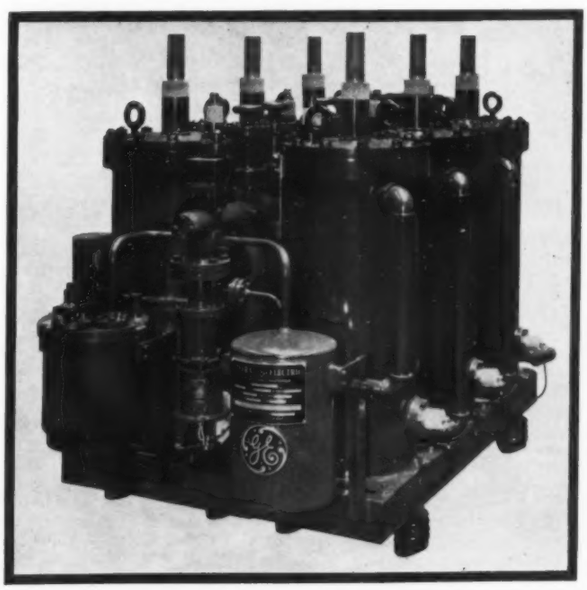
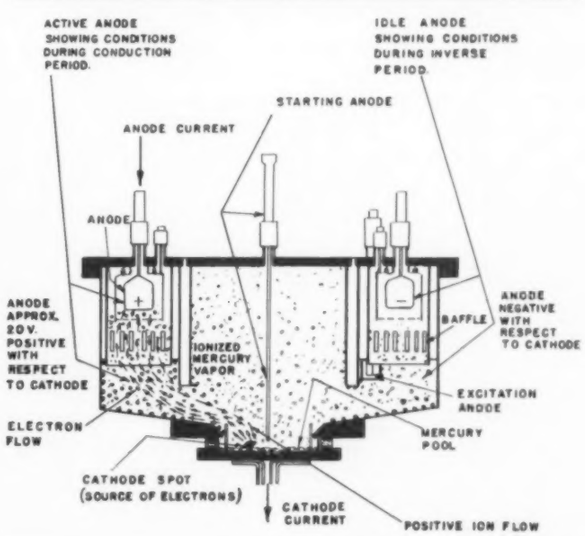


FIGURE 4—The processes with a rectifier during operation are of an electronic nature and a thermal nature. The diagram below shows the electronic action of a multiple anode tank rectifier.



vapor by collision. The cathode spot is maintained continuously during rectifier operation by means of the excitation anodes. When an anode is carrying current it has a positive potential with respect to the cathode of about 20 volts. The electrons, which are negatively charged, are attracted by the positively charged anode and flow toward it in sufficient numbers to carry the anode current. At the same time the positive ions flow toward the negatively charged cathode where they bombard the mercury pool and drive off more electrons.

When an anode is idle it has a negative potential with respect to the cathode and therefore tends to repel electrons and collect positive ions. However, as an anode cannot normally emit electrons, no current will flow in the reverse direction.

The voltage drop across the arc (that is, the arc drop) in a normal rectifier range from 20 to 30 volts and the heat due to this drop results in a thermal action somewhat like that in a steam boiler (Figure 5).

Due to heat generated at the cathode pool, mercury is vaporized at a rapid rate. This mercury vapor flows upward at a high velocity and is condensed on the water cooled walls of the vacuum chamber, so that it flows back into the cathode pool to be used again. The rectifier is provided with a circulating water system which maintains it at a constant temperature at all loads.

The apparatus and arrangement of a complete multiple anode tank rectifier installation with main power circuit and auxiliary connections are shown on the accompanying diagram (Figure 6).

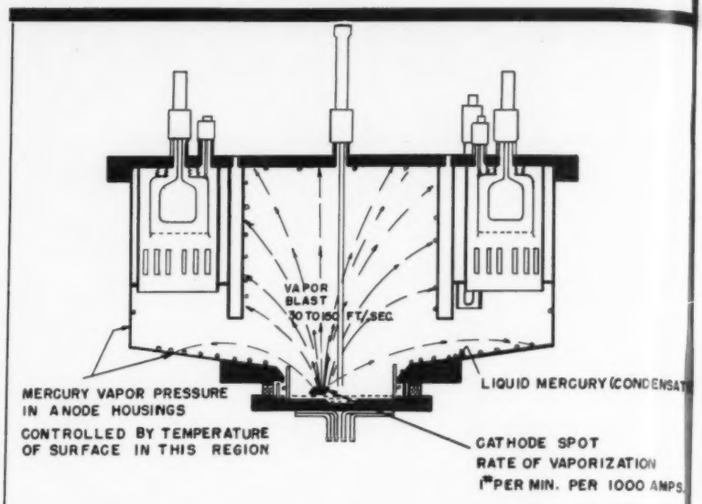

VAPOR BLAST
MERCURY VAPOR PRESSURE IN ANODE HOUSINGS
CONTROLLED BY TEMPERATURE OF SURFACE IN THIS REGION
LIQUID MERCURY (CONDENSATE)
CATHODE SPOT
RATE OF VAPORIZATION
PER MIN. PER 1000 AMPS.

FIGURE 5—The thermal action of the multiple anode tank rectifier is diagrammed above. The action develops from heat generated by the voltage drip across the arc.

OPERATING CHARACTERISTICS

1. Ratings and Performance.

Rectifiers are available in standard sizes from 500 to 3000 kw at 250, 600, 1500 and 3000 volts. These standard units are designed for short time ratings comparable to those of rotating apparatus. A rectifier can withstand successive momentary short circuits of the d-c output without physical damage.

The load rating of rotating d-c apparatus is determined primarily by heating, since operation at long continued overloads may cause serious deterioration of the insulation, even though the commutating limit is not exceeded. However, the insulation used in the rectifier is not subject to deterioration even at temperatures far above the normal value. Therefore the load rating of the rectifier is not determined directly by heating, but is limited by the failure of valve action, or "arc-back", which is the equivalent of a flashover on a rotating machine.

Arc-back is due to the formation of a cathode spot (that is, a source of electrons) on an anode. In the normal rectifier there is only one source of electrons which is the cathode spot on the surface of the mercury pool. However, under abnormal operating conditions, such as for example, excessive sustained load, mercury condensation on the anodes due to low temperature, or high foreign gas pressure due to a leak, a cathode spot may be set up on an anode resulting in an arc-back.

During arc-back one or more anodes pass current in both directions, causing a short circuit on both d-c and a-c systems. In the event of arc-back, service is interrupted by the tripping of the breakers and there is a drop in vacuum on the rectifier due to the evolution of gas caused by local heating from the cathode spot on the anode. However, the gas is pumped out rapidly, and the rectifier may be returned to service automatically in a few seconds. Unlike a flashover on a direct current machine, the arc-back, if promptly interrupted, does no damage to the rectifier.

2. Efficiency.

Figure 7 shows the comparative efficiencies of mercury arc rectifiers, synchronous converters and motor generator sets for 600 and 250 volt service.

As the main loss in the rectifier unit is due to the voltage drop across the arc, and this is practically independent of the output voltage, a higher efficiency is obtained on 600 volt units than is possible with the 250 volt unit. The arc drop of the single anode tank is lower than that of an equivalent multiple anode tank, and thus the efficiency of the single anode tank rectifier is appreciably better than that of the multiple anode type at 250 volts, and slightly better at 600 volts.

3. Power Factor.

The power factor of a rectifier is determined by the transformer connections and the constants of the transformer, and cannot be adjusted during operation as is the case with synchronous converting apparatus. The power factor of the rectifier is less than unity as a result of the combined effects of wave distortion and transformer magnetizing current. Figure 8 shows the power factors for typical 6 and 12 phase rectifier units with transformer constants chosen so as to give a shunt regulation characteristic having about 5 per cent regulation.

4. Voltage Regulation.

The simple rectifier has a voltage characteristic similar to that of a shunt d-c generator. The output

voltage of the rectifier is fixed by the transformer secondary voltage and is of the same order as the secondary line to neutral voltage. The percentage of d-c regulation is determined largely by the transformer reactance which may be varied to suit a particular application. The majority of present rectifier installations have a voltage regulation of approximately 5 per cent from 5 per cent load to 100 per cent load.

A small range of voltage variation may be obtained by means of special transformer circuits. If the transformer is arranged for tap changing under load by load ratio control a wide range of voltage control may be obtained. However, by providing the rectifier with grids, a simple means is obtained for varying the rectifier output without changing the transformer circuit. Figure 9 shows the regulation characteristics for both a simple rectifier and also a grid controlled rectifier.

5. Grid Control.

If an alternating voltage is applied to the grids of a rectifier, the instant at which the main anode fires may be delayed, thereby reducing the d-c output voltage as shown in Figure 10.

The anode is prevented from firing if the voltage on the grid is negative. The point at which the grid becomes positive, allowing the main anode to fire, may be varied by means of either a selsyn or a d-c bias in the grid circuit.

By the use of grid control it is possible to obtain various regulation characteristics. For example, if the grid voltage is adjusted by hand, a series of voltage characteristics such as those shown in Figure 9 may be obtained. Or, if the grid voltage is under regulator control, the rectifier may be given a flat, a rising, or a drooping voltage characteristic, or a characteristic which will hold voltage up to a pre-determined value of current, and then reduce this voltage to prevent the current output exceeding the desired value.

When the rectifier is operated at reduced voltage by means of grid control, its power factor is reduced in approximately the same percentage as is the d-c voltage and it is therefore, usually not desirable to operate a rectifier continuously with a reduction in voltage greater than 15 per cent. However, where reduced voltage is required only for a short period, as in starting a motor, the output voltage may be reduced to zero, so that a magnetic control is rendered unnecessary. For long time operation at reduced voltage a combination of grid control and of transformer tap changing by load ratio control may be used, giving smooth voltage control over a wide range without serious impairment of power factor.

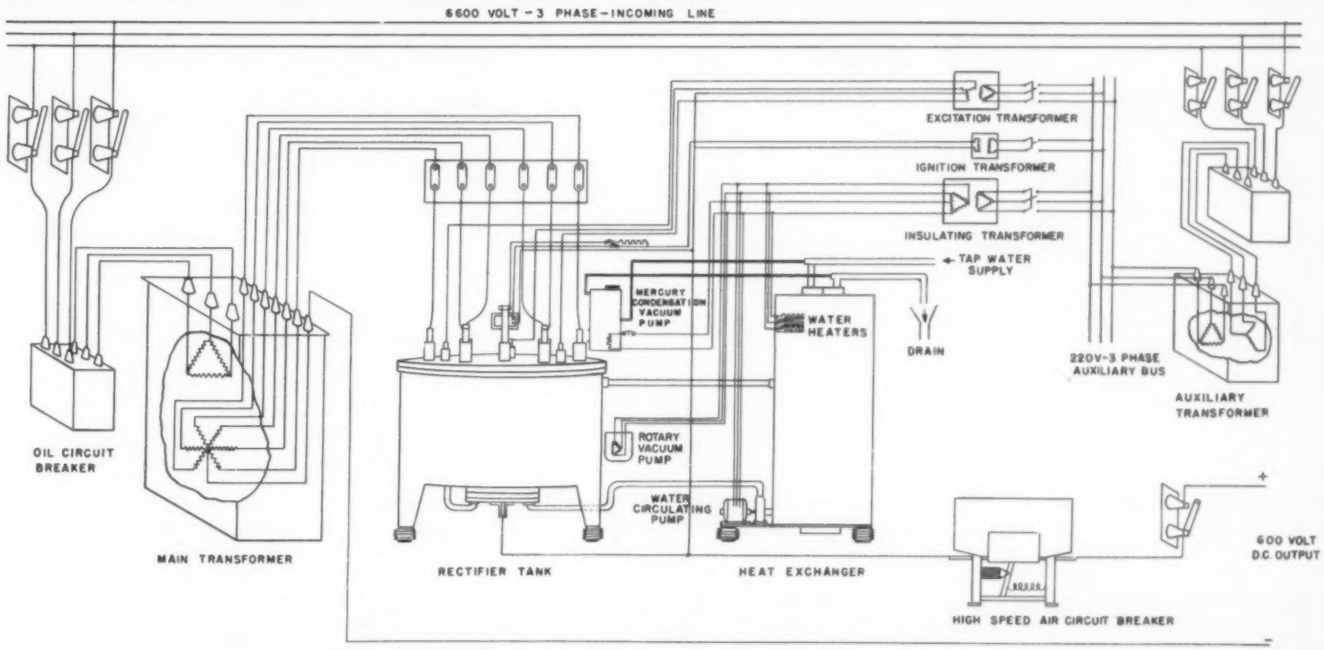


FIGURE 6—A schematic diagram of a rectifier and its auxiliaries, in a system producing 600 volt, d-c power from 6600 volt a-c input.

A grid controlled rectifier may be arranged to regenerate (that is, operate as an inverter), by reversing the d-c leads and shifting the phase of the grids. It is necessary to reverse the d-c leads as current will flow through the rectifier in only one direction. The use of rectifiers for reversing mill service has been suggested but does not seem practical. To eliminate heavy reversing contactors and maintain a smooth flow of power it will be necessary to furnish two tanks, one to operate as a rectifier and the other as an inverter. (Installations of this type have been made in Europe). Furthermore,

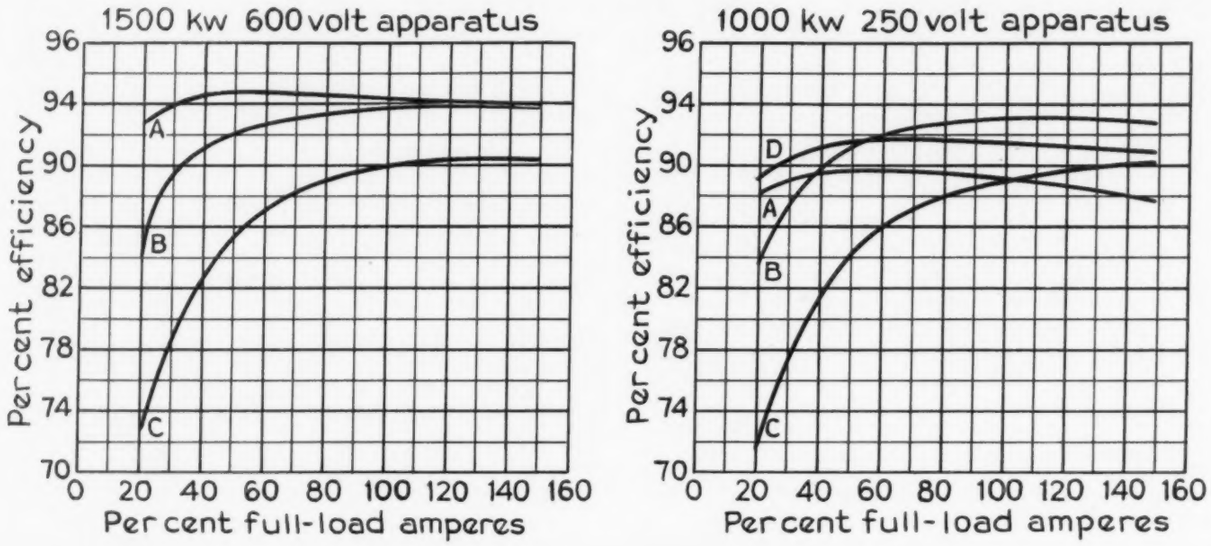


FIGURE 7—Comparative overall efficiencies of a-c, d-c conversion apparatus.
Curve A—Multiple anode tank mercury arc rectifier.
Curve B—Synchronous converters.
Curve C—Synchronous motor generator sets.
Curve D—Single anode tank mercury arc rectifier.
Power supply 6600 volts, 3-phase, 60 cycles. Synchronous motors at unity power-factor, full load excitation maintained at all loads.

the line disturbance produced by the low power factor incidental to low voltage operation may prove objectionable.

6. Reliability.

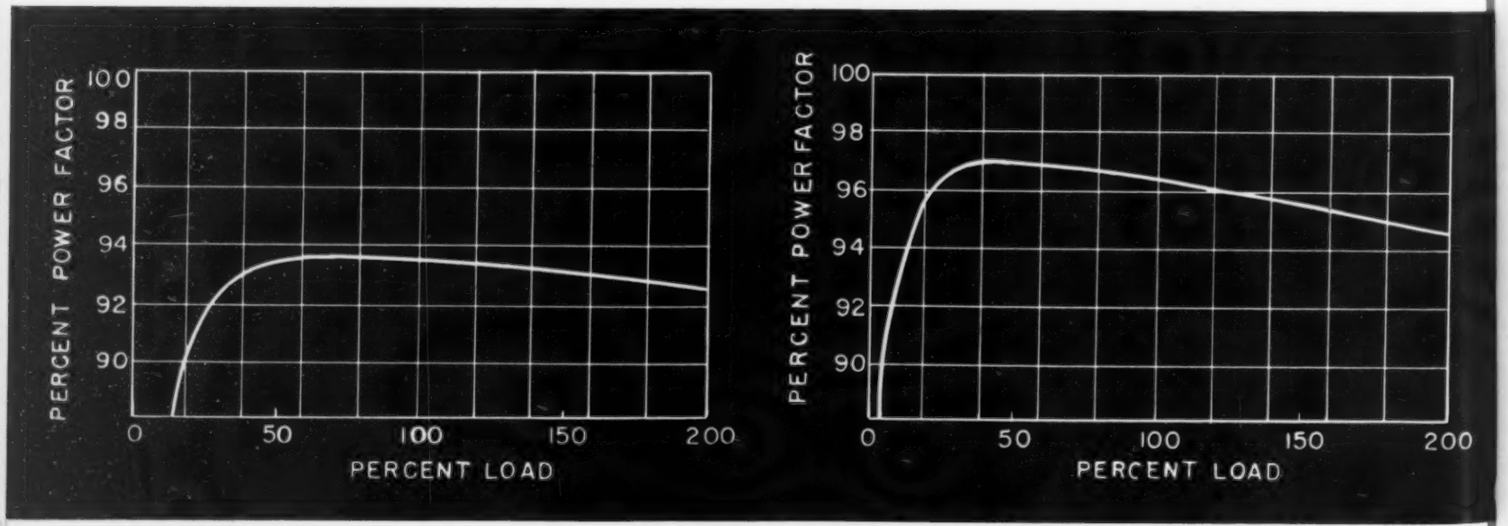
Operating experience has shown that the rectifier is capable of reliable operation over widely varying types of service. Its ability to handle rapidly fluctuating and intermittent loads have been well proven in railway service. For example, the first of the 3000 kw, 3000 volt rectifiers put in service on the Lackawanna Railroad installation, has been in continuous service since July 1930 and its vacuum tank has never been opened.

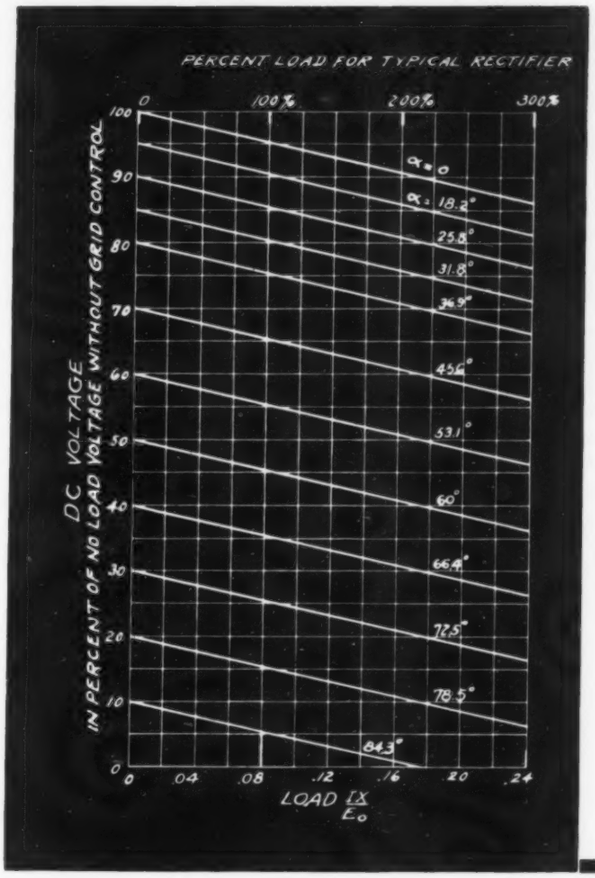
Maintenance on rectifiers is limited to servicing of auxiliaries such as, water circulating pump, and vacuum pumps. There are no large bearings or brushes to wear out and replace.

7. Installation.

When installing a rectifier unit it is necessary only to set it on its foundations, connect it to its transformer, and then degas it before putting it into service. Inasmuch as the rectifier is light and has no moving

FIGURE 8—Power factor curves for typical rectifier units, with transformer constants chosen so as to give about 5 per cent d-c regulation.
Left—Six-phase rectifier with 5 per cent transformer magnetizing current. Right—Twelve-phase rectifier with 3 per cent transformer magnetizing current.





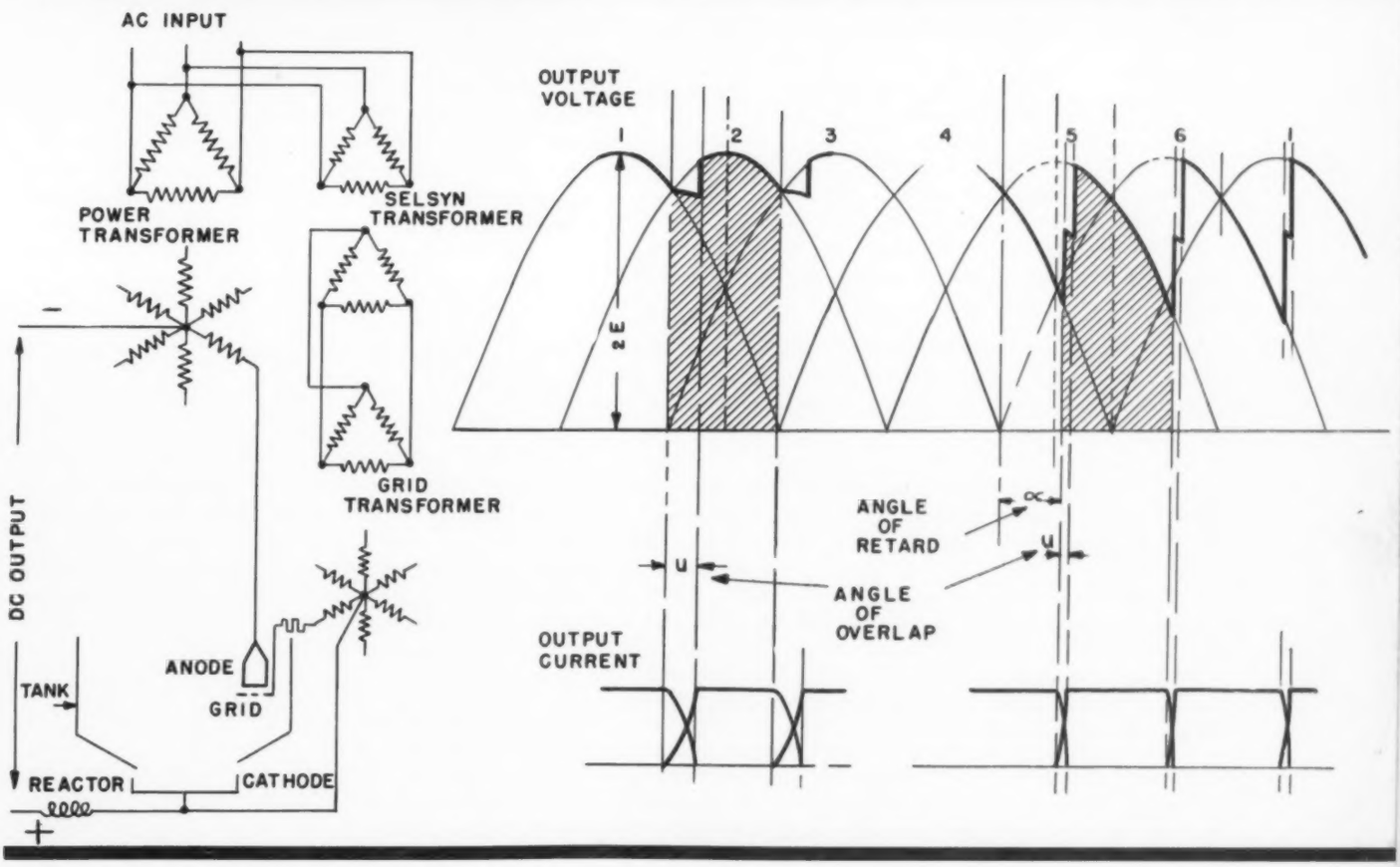
parts a heavy foundation is not required. The degassing consists in passing current through the rectifier at low voltage and thereby heating up the internal parts to drive out the foreign gases. The degassing process generally requires one to three days depending upon the size of unit. Once degassed a high degree of vacuum is maintained by means of the vacuum pumps.

STEEL MILL APPLICATIONS OF MERCURY ARC RECTIFIERS

The performace of a simple mercury arc rectifier is analogous to that of a synchronous converter, in practically all respects except that the rectifier can not regenerate without reversal of connections, whereas the synchronous converter can. However, with the addition of grid control the voltage characteristics of the rectifier may be modified to make the rectifier capable of paralleling successfully with other forms of conversion apparatus, to permit adjustable voltage starting on direct current motors, to provide voltage

FIGURE 9—Voltage regulation characteristics of 6 and 12 phase grid controlled rectifiers with inter-phase transformers (PM3) and highly inductive d-c circuit.

FIGURE 10—D-c output voltage is reduced if an alternating voltage is applied to the grids of a rectifier.



variation for speed adjustment and to permit the rectifier to operate under the control of voltage, current, or speed regulators. The rectifier characteristics thus approach those of a motor generator set, with the exception that regeneration can not readily be accomplished, and that any material decrease in direct current voltage accomplished by grid control alone will iunfavorably affect the a-c system. The efficiency of the rectifier is better than that of the motor generator set at high values of load, and very much better at fractional loads.

The grid controlled rectifier has characteristics which make it suitable for steel mill service, and for some applications may be a serious competitor to the motor generator set. Several typical steel mill systems are discussed below, with a view to determining whether or not the use of mercury arc rectifiers is justified on them.

250-VOLT SYSTEMS

For 250 volt applications, the first cost of the rectifier, including a-c switchgear of 500,000 kva rupturing capacity and suitable d-c switchgear, is from 15 per cent to 20 per cent more than that of a corresponding motor generator set. The cost of rectifier foundations will be lower. If the mill layout permits, the rectifier transformers may be installed out of doors, thus saving on floor space and on building costs. No ventilating equipment is needed, as the losses are removed from the rectifier by mill water. Thus, the ratio of installed costs will be more favorable to the rectifier than the ratio of first cost. However, the rectifier cost, installed, is likely to be higher than that of the motor generator set, except under unusual conditions.

For an attended station the cost of attendance should be about the same for either type of equipment. Maintenance on either unit will be low, with the advantage probably in favor of the rectifier. The rectifier's chief advantage is, of course, high efficiency, particularly at partial loads.

Thus it appears that, at present price levels, the rectifier is justified on 250 volt systems only in those cases where the load factor is low, or in some unusual cases where the ventilation of a motor generator set would prove a difficult problem. However, the continuing expansion of rectifier applications should tend toward reduced costs and thus make the rectifier a stronger competitor in the 250 volt field.

HOT STRIP MILL SYSTEMS

In the present state of the art the rectifier is not justified as the power supply for a controlled hot strip mill.

For 600 volt service the first cost of the rectifier is about the same as that of a motor generator set, and thus its installed cost should be materially lower. Its high efficiency is of particular value on the low load factors imposed by hot strip mills. However, to offset these advantages, the rectifier has several disadvantages. First, its use will mean that it will be impractical to operate the mill at low speed by reduced voltage unless a combination of grid and load ratio control are used. Second, dynamic braking equipment must be provided for the mill motors. Third, and probably the most important, is the fact that the rectifier power factor is lagging and can not well be controlled. On the larger hot strip mill installations it is now necessary to consider the effect of the high peak loads on the a-c system, and in many cases to make provisions for varying the excitation on the motors of the synchronous motor generator sets in order to increase the leading kva at heavy loads so that the voltage regulation on the alternating current bus may be kept within reasonable limits. This type of control is not available with the rectifier. In addition, the rectifier presents a lower impedance to a direct current short circuit than the motor generator set does, and therefore the stresses on the direct current bus and the duty on the air circuit breakers will be considerably more severe with the rectifier than with a motor generator set. On the larger mills short circuit stresses are already becoming a serious problem, and it does not seem advisable to install equipment which would increase these stresses.

COLD STRIP MILLS

Both tandem and reversing cold strip mills require low bus voltage for threading and adjusting the mill, and must start and stop many times an hour. To obtain such operation by controlling the output voltage of a mercury arc rectifier would produce wide and frequent swings in a-c power factor, and might cause objectionable system disturbances. In addition, regenerative braking is vital to both tandem and reversing cold strip mills, and rotating equipment, in the form of boosters, exciter sets, and so on, is needed in any case. Thus, the rectifier does not seem adapted to cold strip mill power supply.

SMALL 600-VOLT SYSTEMS

The rectifier seems very well adapted to the 600 volt systems of the smaller merchant and rod mills, which may require on the order of 3000 to 4000 kw in 600 volts direct current power. The installed cost of the rectifier should be somewhat lower than that of a motor generator set. The various advantages mentioned above, such as efficiency, floor space, and building costs, will apply here. Mills of this type usually use Ward-Leonard control only for starting, and the line disturbances during one or two starts a day should not be objectionable. Since the capacity of the system is small, line voltage regulation and the amount of power in a direct current short circuit are not objectionable features. Therefore, installations of this type seems at present to be the most promising field for the mercury arc rectifier.

Maintenance and ITS RELATION *to* SAFETY ...IN THE METALS INDUSTRY

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▲ MAINTENANCE work properly planned and executed is essential if the safety program of an industrial plant is to be successful. Planned maintenance reduces not only the overall total of man-hour exposure in this class of work, but also reduces the number of unexpected or breakdown jobs, where the pressure of interrupted production militates against thorough preparation for the job at hand, and where the failure of equipment may result in injury to operators or others in the vicinity. Work properly executed implies that repairmen are properly equipped and instructed, and that the damaged or worn equipment is restored to a safe operating condition.

The main objectives of a maintenance organization may be defined as the safety of the maintenance personnel, the safety of operating personnel insofar as keeping the equipment in good condition can contribute, the minimizing of interruptions to production, the control of maintenance costs and the observation and recording of difficulties encountered in the operation and repair of equipment for the benefit of subsequent design and operation. All of these objectives are in complete harmony and progress achieved by attention to any one of these items contributes to the advancement of all the other objectives.

The Steel industry has been closely associated with the development of the safety movement which started only thirty years ago. In 1907 the American Institute of Social Sciences started the American Museum of Safety in New York City. Also in the same year the Association of Iron and Steel Electrical Engineers ap pointed a "Safety Committee", becoming the first technical society to recognize the safety movement and actively pursue the elimination of accidents in industry. In 1908 the Steel Corporation formed a "Central Committee on Safety" which soon developed into an important and busy unit. In 1912 the Association of Iron and Steel Electrical Engineers at Milwaukee, recognizing the necessity for the formation of a national organization, conducted the first cooperative Safety Congress and appointed a committee "to organize and to create a permanent body devoted to the promotion of safety to human life in the industries of the United States". The National Safety Council was formed as a direct outgrowth of the foregoing action.

In the earlier days the safety movement concentrated on safety guards, enclosures and unsafe working conditions. Naturally great strides were made in mechanical safeguarding, but the decrease in industrial accidents was disappointingly small. It was at this stage that attention began to be focused on the less tangible factor of human behavior in relation to safety. Mechanical features of the safety campaign are capable of definite organization and control, and can be brought to any desired degree of efficiency by the proper coordination of inspection, maintenance, and operation of existing equipment, and the engineering and design of additional equipment. Close and unremitting attention to this feature has characterized all successful industrial plant safety programs. The challenging, ever-changing factor in this problem is the prediction and control of human behavior, varying as it does among individuals, and varying again in one individual due to changes in physical condition and mental attitudes and distractions. It is this factor which requires the major attention and concern of any safety program.

Outline of Safety Program

The safety program of a steel mill maintenance department naturally consists of two major divisions; namely, the promotion of the safety of the maintenance crews in the performance of their work, and the safety of operating and production crews, insofar as proper maintenance of equipment and development of improvements, based on observation of operating difficulties, can contribute to the safety of such crews. Due to the nature of the work of the maintenance man, he is called upon to work around all types of equipment in his department; and if he is working out of the Central Shops, his duties will take him into all parts of the plant. For this reason he is subjected to a greater variety of hazards than the average employee, a fact which should be borne in mind in the selection of personnel.

The preferred type of man for this work should be alert, able to analyze a situation and arrive at a prompt decision as to the required action. He must be able to

C. J. SMITH

include in his analyses the probabilities of dangers to himself and crew and minimize these dangers by proper planning of the work. Men are naturally placed in an organization by their interest and capability in a given line of work. In maintenance work further qualifications are necessary based on the adaptability of men to the aforementioned varying conditions. For example, some men can climb at considerable heights, with no ill effects, and others cannot; and this and other limitations of individuals must be known and considered in the assignment of work.

Proper Equipment, Special Clothing Essential

With crews properly selected for their work, the next consideration is that of proper tools kept in good condition, and special clothing or equipment where required for safety. This, of course, includes goggles, foot guards or safety shoes, leggings, gloves, aprons and helmets for burners and welders, safety helmets for men exposed to falling material, respirators for dusty locations, and oxygen apparatus where noxious fumes or gases may be encountered.

Plants operating blast furnaces and utilizing their by-product gases, which are high in carbon-monoxide content, must pay particular attention to the safety of operating and maintenance personnel, in all locations where this gas may be encountered.

Gas detectors are available which are arranged to show gas concentration on the dial of a suitable meter, calibrated to read directly in per cent of carbon-monoxide. These devices may also be arranged to ring a bell or light a light or both, at a predetermined concentration of carbon-monoxide. These devices can be operated continuously, giving a continuous check, or at suitable intervals. Such devices should be used whenever workmen need to enter any confined space where gas may be encountered as in gas mains, blast furnace stoves, gas washers, engine room basements, etc.

The gas detector is recommended for areas which are normally reasonably free from gas, but which may be subject to gas due to unexpected causes. In areas where gas is expected, and where the presence of workmen is required for a short repair or operating job, some form of breathing apparatus must be employed.

Hose masks may be employed where there is an unquestionably pure air supply within reach of a reasonable length of hose, and a hand-operated blower used to force a supply of pure air to the wearer of the mask. In atmospheres where there is sufficient oxygen to sustain life, another type of mask and breather equipment may be used, wherein the carbon-monoxide is removed by passing the air through a suitable chemical filter.

When the oxygen content of the air is at all questionable, a complete oxygen breathing apparatus must be used. These are available in compact relatively light form and afford complete protection for the wearer for periods up to one-half hour. Automatic features provide proper adjustment of oxygen supply to suit conditions from rest to heavy exertion, without manipulation by the wearer. Regenerators are incorporated which remove carbon-dioxide from the exhaled air in the breathing bag, allowing re-breathing.

The foregoing apparatus is all of a preventive nature, and to be effective, must be applied in anticipation of a workman's exposure to harmful concentrations of carbon-monoxide. To guard against unexpected exposure definite and detailed procedures must be developed and strictly observed. For example, men must not work, or go, alone into confined areas where gas might be encountered—as in engine room basements, gas washer enclosures, etc. Notwithstanding careful planning, accidental exposure may occur and remedial procedures must be fully developed. These include the application of artificial resuscitation to persons overcome by gas, and the supplying of oxygen through the use of inhalators. Men must be available in all crews who can administer treatment correctly and promptly, and frequent drills in this procedure are essential.

The next step in safe maintenance is to insure the proper line up of men and equipment on the job at hand. Proper clearance with operating departments insures the attention of those supervisors most intimately acquainted with details of operating conditions and attendant hazards, and whose advice on such matters is very important. Furthermore, this minimizes the likelihood of unexpected operation of equipment and calls the attention of operating men to the presence of outside men in the department, in locations where normally no one would be working.

On movable equipment, all sources of power and control must be safeguarded by locking out such power control apparatus by the use of safety locks. Proper line up of the use and removal of safety locks is of prime importance. If more than one group of maintenance men are working on the job, each such group should attach a safety lock, to be removed by no one, except the man responsible for a particular group, and then only after careful check, which accounts for each man in his group. Facilities should be provided so that locks are attached directly to the locking-out device and capable of removal individually—for example, snapping one lock into another lock, so that the removal of the first lock removes the protection of the other groups, should not be tolerated. If one supervisor is responsible for all groups employed on the job at hand, then one safety lock is sufficient, if not removed until every man assigned to the job is accounted for.

Working platforms, where required, must be con-

structed in accordance with accepted standards, with railings and approaches and other features required by the job, and makeshift or substandard construction must not be tolerated. The need for railings and warning signs is to be carefully analyzed, as well as the need for special watchers.

Before the work is started it is essential that all men are lined up not only as to their duties, but also as to special conditions requiring their attention to insure a safe conclusion to the work at hand. Here again the operating department can be of great assistance in calling attention to hazards which may be encountered by men getting away from the working area, where all possible precautions have been taken for their safety, and into a location where they are not expected to be, and where hazards may not be entirely obvious.

Changes from the agreed procedure should not be made by any individual or group until it is certain that all concerned are aware of the proposed change and that no unexpected hazard will be introduced by such a change.

Upon completion of the job, a complete clean up should be made, removing all scrap and unused material, and restoring the surroundings to an orderly condition. All guards and safety appliances must also be restored before turning the equipment over for operation. Furthermore, during the progress of the job strict attention to orderliness is required. All materials and tools should be kept in order, and no accumulation of scrap materials or tools under foot, or interfering with progress of the job can be tolerated, if accidents are to be minimized.

Good light is essential to the safety of maintenance work, and sufficient temporary lights should be used to insure adequate illumination, provided that the light intensity provided for normal operation is insufficient for repair work. Portable man cooling fans may often increase the comfort and efficiency of the workmen and minimize the hazards inherent in fatigue and discomfort.

Self Interest of Individual Needed for Successful Program

On the basis of the human element being the major problem in the elimination of accidents and their attendant injuries, the safety program must be designed to emphasize to the supervision and workers the necessity of being safety-minded at all times. The most effective influence in selling any proposition is an appeal to the self-interest of the individual. If he becomes convinced that he can personally benefit by the elimination of accidents, he is apt to accept the safety program and become a safety booster.

Fortunately the primary objective of safety is the welfare of the individual and no hedging is necessary in selling the proposition on that basis. While injuries have become increasingly expensive to employers due to liberalized compensation laws, court awards and voluntary expenses in connection with such cases, the welfare of the employee is yet the primary consideration. Unfortunately many employees, particularly those of long service, whose familiarity with the hazards of their work has developed a contempt for danger, feel that safety rules are all right for anyone who needs them, but that the one who needs them is some one else. Another obstacle to the development of good safety practice is the tendency of individuals to decide to suspend or ignore a known safety practice if it involves additional effort on their part to comply with the rule; or if it appears that production may be unduly interrupted or the completion of the job delayed.

The younger employees, particularly boys starting on their first job in an industrial plant, provide the best possibility for the development of safety-minded workmen. They are yet in their formative years and have no bad working habits which would need to be eliminated. Of this group, the trade apprentices offer the best opportunity for thorough safety training. The apprentices, while usually a relatively small group, are carefully selected with reference to their ability to absorb knowledge of their chosen trade under a definite system of instruction. Both the personnel and the training system offer ideal opportunities for effective instruction in safety-mindedness, and any apprentice program which does not take full advantage of this opportunity is in need of revision. Safety instruction should be made an integral part of all instructions relative to shop practice. Both the foreman and the instructor for class room work should develop the habit in the apprentice of analyzing all operations from the standpoint of safety, as well as from the standpoint of efficiency, accuracy and other attributes of good workmanship.

Continual emphasis is essential on the facts that no one can elect to be exempted from the rules and that rules cannot be suspended at will for the sake of production, and that the chief reason for this is the welfare of the individual. A review of accidents to men in a line of work similar to that done by the individual or group, that is being instructed in safety, goes far to dissipate the idea that anyone is exempt from the need of applying the safe working rules. Attention must be called to the possible suffering, loss of earnings and permanent reduction of earning power connected with injuries, and the effects on families and dependents.

Pride of Achievement Effective Appeal

Another effective appeal of a personal nature is to the pride of accomplishment of the individual. Many men have this inherently and are easily sold on the idea of excelling as a safety booster. Loyalty, another admirable characteristic of human nature, may also be turned to advantage to the support of a safety program —loyalty to a foreman or superintendent, who has indicated a sincere interest in his men's welfare and who is, therefore, actively interested in safety, automatically requires good performance.

The desired emphasis can be obtained only by repetition of supervisors stand on safety matters, and the examples of insistence on safe practice at all times. This is best accomplished by a fully developed plan, strictly adhered to. All men should be called into group safety meetings periodically, and in many plants the minimum requirement is one such meeting per week. These may be large or small groups, held in the field or in the office, but held as scheduled. Departure from the schedule due to press of work, immediately suggests that safety is not first, but is subordinate to production, and the sincerity of the program is subject to questioning. The group meeting is most effective when conducted as a conference, rather than as a lecture or

instruction period. More suggestions are obtained and interest is better sustained where any and all men are allowed and expected to take part in the discussion. Each man who thus puts over a good safety idea, and sees his suggestion materialize into a working practice, or a safety device, is going to be personally interested in safety, and will put greater effort into trying to develop other ideas. Likewise, other individual workmen will be interested in making a similar showing.

To maintain interest and insure continuation of safety suggestions, definite follow-up of suggestions is essential. The suggestions should first of all be recorded in minutes of the meeting with credit given to the individual making the suggestion. Each suggestion must be disposed of by approval or disapproval and this action brought to the attention of the man and group involved. This review of suggestions should be made by the foreman or superintendent of the department or the shop or departmental safety committee. On matters concerning other departments, the suggestion should be forwarded to the supervisors of the department affected, and the disposition made be brought back to the originating group.

This procedure may appear obvious, but unless completely developed and consistently followed, there will be no sustained interest in the safety meetings.

These meetings should be reported and copies of the minutes forwarded to all interested parties, as department superintendent, director of safety, superintendent of industrial relations, etc. These minutes record all changes in equipment or methods made in the interest of safety, and prevent suggestions and ideas from becoming lost through inaction. The weekly meeting should in no way detract from frequent observation of workers and their methods, and further instruction in safety at any time.

Periodic Meetings of Supervisory Personnel Necessary

Weekly meetings of foremen, with superintendent or assistant presiding, are essential to develop and inspire the programs of the group meetings referred to above.

Preventive safety requires attention to those conditions and practices which are leading to accident and injury. Usually no one is injured the minute an unsafe condition develops, or the first time an unsafe practice is followed. It is the failure to recognize these things as danger signs which allows them to continue until the damage is done. Here again a fully organized program is essential.

This program naturally devolves upon supervision, since the individual workman cannot be expected to assume any great measure of responsibility for conditions, and is hesitant about reporting unsafe practices of fellow workmen.

The foremen must be definitely charged with the responsibility of observing and reporting unsafe practices. Periodic meetings where these reports are reviewed, are essential to the effective functioning of such a system. This plan develops good practice standards for every detail of the work and insures that all concerned are fully acquainted with the working rules, since men cannot be disciplined for the infraction of rules which are not known and understood. To insure fairness, the first observed infraction is called to the man's attention, whereas subsequent infractions are dealt with more severely.

This system supplemented by the periodic group meeting of workmen, with minutes recording the itemized discussions and instructions, and identities of men so instructed, gives a very effective check on the safety performance of each man. This system has been observed in practice and the results are exceptionally satisfactory.

Likewise, under the heading of prevention come the near accident and minor injury cases. These must be treated on the same basis as serious injury cases, since the only difference in most instances is the element of luck. The fact that a man was missed by falling material, or that no one was actually on a scaffold knocked down by a crane, does not excuse the unsafe practice which resulted in such a potential serious injury case, and the underlying causes should be developed just as carefully as if someone were killed or crippled. Here again the principal burden falls on supervision, and a definite check up system is essential to insure proper attention. It is reasonable to expect a foreman has opportunities to observe such occurrences at frequent intervals, and failure to report such items over any extended period of time indicates either a lack of observation or indifference to the prevention of accidents.

Proper Discipline Essential in Program

Proper discipline is essential in the conduct of an effective safety program. Accident statistics show that injuries occur on the streets and in the homes in tremendously greater number than in a well organized industrial plant. The chances of a man being injured outside of such a plant may be as much as 40 times as great as the likelihood of injury at work. The wag who suggested that the foreman should congratulate his men each morning for having arrived back to work safely was only drawing a logical conclusion from the foregoing comparison.

The fundamental reason for this difference is that the organization and discipline of the industrial plant is lacking on the streets and in the home. There is no public official who cares to accept the responsibility for traffic rules rigidly enforced. However, if public sentiment condemned such authorities for the slaughter on the highways in the same way that industrial plant managements are criticized for a safety record which is not nearly so bad, great strides could be made in public safety. And in the home no one is severely criticized for the defective step-ladder, the loose stair carpet or the poor condition of tools or electric wiring, which go right along taking their toll in injuries.

Contrasted to these conditions, is the well organized industrial plant which definitely assigns the responsibilities of the working forces and holds each man accountable for living up to these responsibilities.

Discipline is not incompatible with the humanitarian objectives of a safety program. Just as the enforcement of the general laws requires discipline, in the interest of "keeping the peace", so does the successful safety program require discipline as a deterrent to practices which will work injury upon those who violate the rules, and upon those who may be involved through no fault of their own.

The foreman who condones violations of established safety practice, or who avoids disciplinary action in order to shield the offender from embarrassment, is not acting in good faith with the plant management and is not discharging his moral responsibility of looking out for his men's best interests.

Fair-minded men do not resent reasonable discipline fairly applied since they know that such procedure is essential to their protection from their own shortcomings, as well as from the actions of others. Disciplinary measures, ranging from reprimand to discharge, if applied according to a known plan, will create little or no resentment and will be effective in decreasing injuries.

The hazards incident to maintenance work can be minimized by methods which anticipate and reduce the number of breakdown jobs. This reduces the amount of work and corresponding man hour exposure, and allows most of the work to be done on a planned basis. The most essential practice in such a program is systematic, thorough and frequent inspection of all equipment, with a follow-up system which will insure that unsatisfactory conditions are corrected as promptly as production allows or economic considerations dictate.

Delegating Function of Observation to Operators Helpful

If the maintenance foreman's territory is small this inspection can be made personally. However, the usual division of a steel mill maintenance foreman is too extensive and too many other demands are made upon his time to allow personal attention to all items of equipment. It is then necessary to delegate this important function to operators, oilers, engineers, electricians, etc., whose work brings them into a position to closely observe the condition and functioning of each piece of apparatus.

In power houses, boiler houses, pumping stations and similar station jobs the engineers, oilers, pump tenders and electrical operators are primarily occupied with operation of the equipment and close and continual observation is automatically obtained. Such close observation is accepted as necessary due to the importance to production and the fact that little spare capacity is provided. Likewise, the standard of maintenance is high, being kept as far as possible on a preventive basis. The jobs are usually well planned, the crews experienced and efficient, and all tools and special equipment at hand, resulting in efficient and safe performance.

The majority of mill auxiliary equipment does not get the same degree of attention and maintenance. Here the operator, in general, has no interest in the apparatus, except that it responds to the controls, and little or no responsibility for keeping the unit in operating condition—hence the necessary, fully organized maintenance crew to take care of such equipment. The only exception to this is the craneman who may have limited responsibilities as to the inspection, lubrication and adjustment of his machine, and certain other machine operators.

Overhead traveling cranes, gantry cranes, repair trolleys and various types of hoists comprise a class of equipment which require special attention from the standpoint of inspection and preventive maintenance. Due to the hazards of falling material, whether casual material, broken parts of the equipment, or loads dropped due to failure of mechanisms, every precaution must be taken to keep this class of equipment in good repair. It has been found desirable to supplement the work of the foremen and repairmen charged with the proper maintenance of such equipment by the use of Crane Inspectors.

The Crane Inspector goes over each equipment in detail, recording all items of a mechanical or electrical nature which need adjustment or replacement. This survey provides a double check and does not lessen in any degree the responsibility of the above-mentioned foremen and repairmen. Copies of these reports are forwarded to the Superintendent and foreman involved, as well as to the Plant Safety Department head. All recommended repairs or alterations must be disposed of, either by being carried to completion, or by being rejected for cause by the proper supervisors.

The inspection covers cleanliness and orderliness of the equipment in the interest of minimized fire hazard and increased safety of operators and repairmen. Safety equipment, such as sanders, fire extinguishers, hand lines, safety belts, gongs, warning lights, light extension cords, gear guards, etc., is checked. Loose or scrap material on the cranes, approaches or runways is not tolerated. Loose, worn or broken parts are itemized and recommended for proper corrective action.

Inspections at intervals of one to two months have been found to be sufficient for average conditions, with more attention given to particularly hard-worked cranes. Unusual operating conditions, or failures of parts may make it desirable for the inspector to make special checks and reports when requested.

Accident experience should be utilized to minimize the occurrence of accidents and injuries. By analyzing the conditions and practices involved in injury and near injury accidents, and developing and carrying out improvements in equipment and practice, such experience can be made to yield a return in progressively lowered accident frequency.

In this connection the Maintenance Department supervision plays an important part. Plant Safety Committees usually include the heads of the Electrical and Mechanical Departments, departmental safety committees and the departmental maintenance foremen. In the review of accidents it is the responsibility of these men to determine the extent to which mechanical and electrical equipment contributed to the accident, due to lack of maintenance, or failure of parts, and to exercise judgment as to when unwarranted blame is placed on the condition of equipment, in order to detract attention from possible faulty operation of facilities. Due to their knowledge of the possibilities, as well as the practical limitations of mechanical and electrical devices, they are of assistance in developing corrective action, either in the direction of better operating practices, the rearrangement of equipment, or the addition of safety devices.

The foregoing discussion may appear to be laboring over details which appear obvious. However, accident experience all to often indicates that the obviousness of hazards and necessary preventive procedures, comes only after the injury has occurred. Maintenance work and safety work alike, depend for success upon continuous attention to more or less obvious details.

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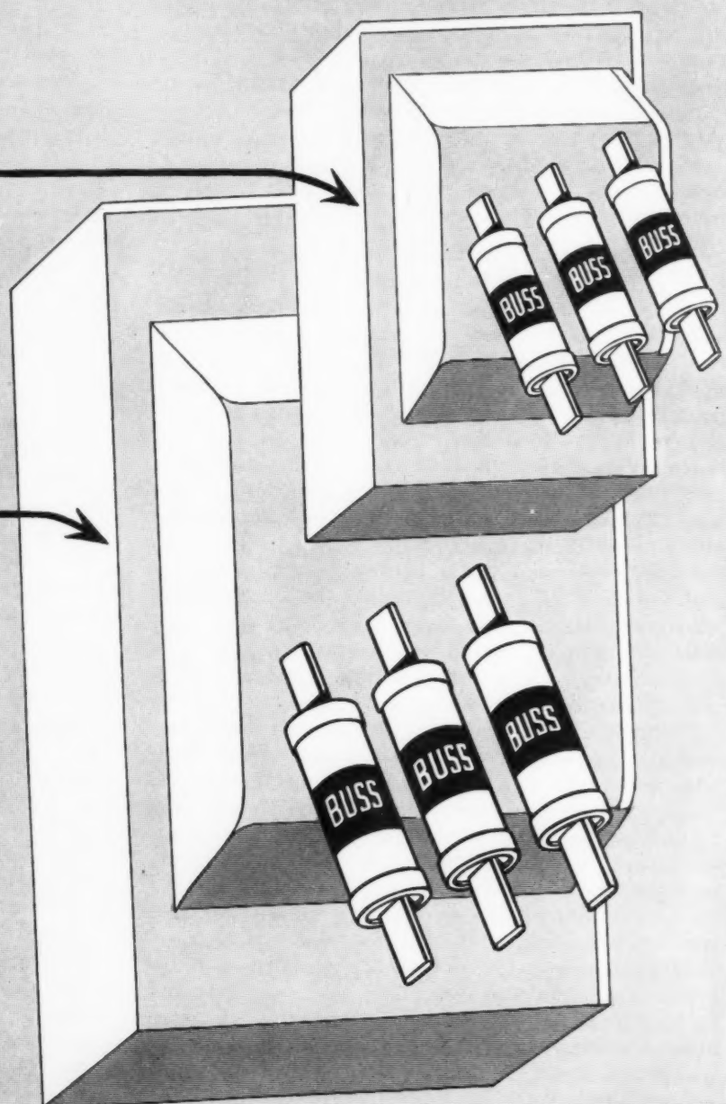


BUSS

ADVERTISING PAGES REMOVED

IMPROVED TYPE OF MOTOR-DRIVE

▲ An improved design of Reliance reversing motor-drive for planers, makes use of armature speeds of 150-600 rpm. and 100-600 rpm. as against former standards of 250-1000 rpm. and 200-600 rpm. Field horsepower capacity is maintained over the entire range. Since there is less stored energy in the armature at the reduced speeds it stops quicker and gets under way quicker at the end of each stroke. Time clipped from the reversal period is changed to cutting time with a consequent improvement in the production record of the planer. Cost comparisons, wherein various operating conditions have been assumed, indicate that the moderate added cost of the quicker-acting motor will be returned by savings made within the first year.

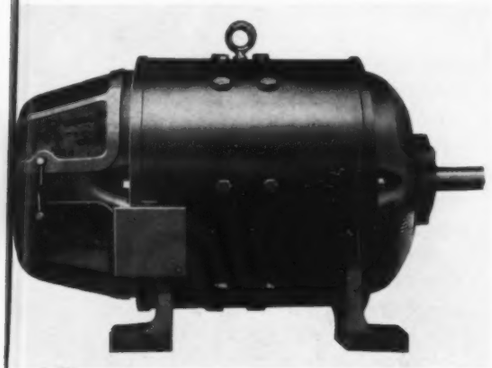
Improvements in the control equipment include a new pendent control station with extra buttons which bring added convenience for setting-up operations.

The master reversing switch mounted on the planer bed has been made direct-acting to speed up its operation.

The rheostat panel for control of cutting and return speeds is now a separate unit so that it can be mounted within easy reach.

Design features of the main control panel combined with improved electrical design of the motor also contribute to speedier action.

Improved type of reversing motor drive for planers where field horsepower capacity is maintained over an entire range.



NEW TYPE ELECTRIC FORK TRUCK

▲ Elwell-Parker's type F-11 tiering, tilting, telescoping fork truck has rated capacities up to 5,000 pounds and has four speeds forward and four reverse. The power circuit is closed and broken by a mill type magnetic contactor which is electrically interlocked with the controller. Truck has two wheel drive and four wheel steer.

The power plant is equipped with an Elwell-Parker 500 per cent overload, heavy-duty and high torque motor. The motor being direct con-

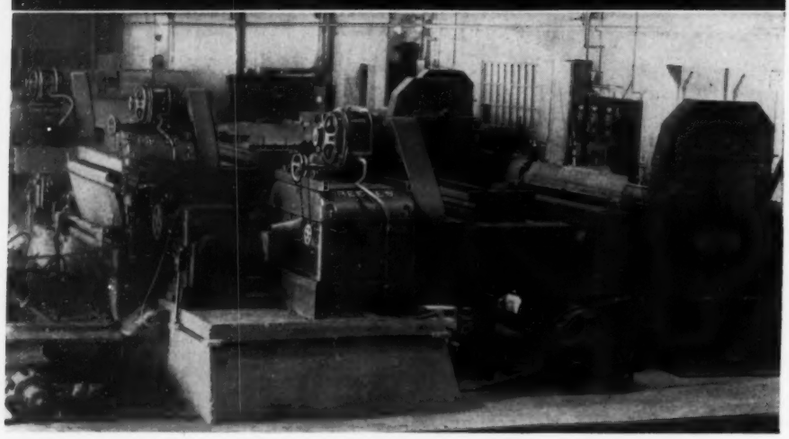
Telescoping fork truck with rated capacities up to 5000 pounds and four speeds forward and four reverse.

nected to free coasting worm and gear.

All parts are easily accessible and design is such as to permit truck to travel over uneven floors without transmitting strains to mechanism.

In this fork truck, as in other Elwell-Parker equipment, the company has emphasized safety to men, machine and loads. As an example—a dynamic brake supplements the travel brake and a solenoid brake on the hoist motor locks load in position unless released by the application of power. Regenerative braking supplements the solenoid brake and returns current to battery when lowering load. A ratchet protects the mechanism at the bottom of down travel of load and an electric clutch protects mechanism at the limit of up travel, and when overloaded. Forks stop automatically at either limit.

NEW ACCURACY IN TIN POT FEEDS



Operating 24 hours a Day, Three Enclosed Design REEVES *Transmissions Provide Tin Pots in Ohio Mill with Instant, Accurate Changes in Feed Roll Speeds.*

• To permit instant changes in feed roll speeds as required by different gauges of sheets, and to maintain the selected speed without fluctuation, these tin pots were equipped with REEVES Variable Speed Transmissions. Result: minimum of wasters at inspection table and faster production.

REEVES Transmissions and constant speed a. c. motors were used although d. c. was available in the mill. Reasons: greater over-all operating economy of a. c.-Reeves equipment and need for a drive extremely flexible in speed adjustability, but also positive in maintaining a *uniform* speed.

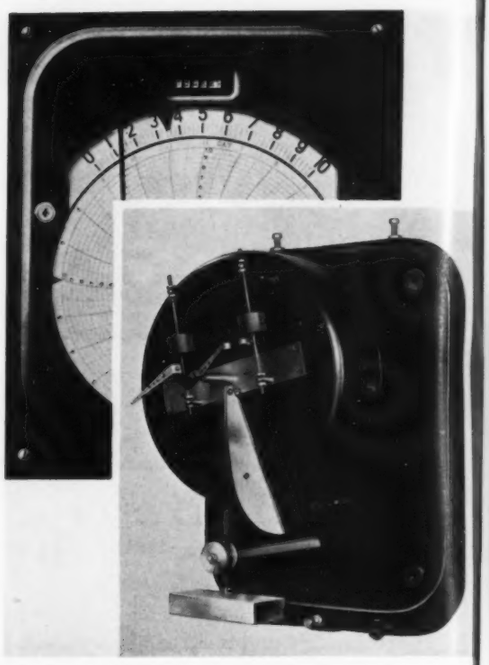
Here, as in hundreds of other installations in steel mills, the dependability of REEVES Speed Control is convincingly demonstrated. REEVES enclosed units are fully protected against abrasives, liquids, or fumes. In sizes from fractional to 125 h. p. capacities; speed ratios from 2:1 to 16:1 inclusive. Many different controls—manual, remote, automatic.

★ ★ ★

SEND FOR THIS BOOK

NEW 124-page Catalog-Manual G-384 of Speed Control. Describes and pictures how the modern REEVES units meet your individual requirements correctly. REEVES PULLEY COMPANY, Dept. IS, Columbus, Indiana.

REEVES SPEED CONTROL



This above instrument is designed for operating on a differential as low as two inches of water.

FLOW METER FOR GAS MEASUREMENT

▲ PUBLICATION 2089 has just been issued by the Cochrane Corporation of Philadelphia, Pa., introducing the Cochrane ring-balance flow meter for low pressure gas measurement. This instrument is designed for operating differentials as low as 2 inches of water and is particularly applicable to measurement of gases at pressures below those for which the customary types of mercury-sealed flow meters are suitable.

The meter consists of a ring-shaped hollow body, rotably supported on knife edges at its center, so as to be capable of turning freely. The annular body is partly filled with water, oil or air anti-freeze liquid, and is divided at the top by a partition wall, to each side of which a flexible tube is led for the purpose of subjecting the unit to the differential pressure from an orifice or flow nozzle through which flow is to be measured.

When flow occurs through the orifice plate, the resultant differential pressure causes the liquid in the ring balance to be transferred from one side to the other, whereupon the ring balance rotates to a new position of

equilibrium. Motion is maintained proportional to flow by a suspended weight and cam.

The meter is characterized by exceptionally high operating power for low pressure gas measurement, charts and indicator scale graduated uniformly in terms of flow, a calibrating weight by means of which the accuracy may be checked quickly, direct-reading integrator, and guaranteed accuracy.

NATIONAL STEEL TO SPEND FIVE MILLION

▲ National Steel Corporation has announced that $5,000,000 will be spent on plants of the Weirton Steel Company at Weirton, West Virginia, in further diversification of products.

The improvement will provide production facilities for a number of new products which will include a greatly increased range of structural shapes, sections for car building and ship building, a full line of steel piling and other special sections. The new equipment also will roll all sections of rails including the 152-pound section, now the heaviest used by the railroads of the country.

Work will be started on the program immediately and the new facilities are expected to be in operation by July 1, 1939. This program is in line with the consistent policy followed by National Steel Corporation since its organization to continuously diversify its line of products.

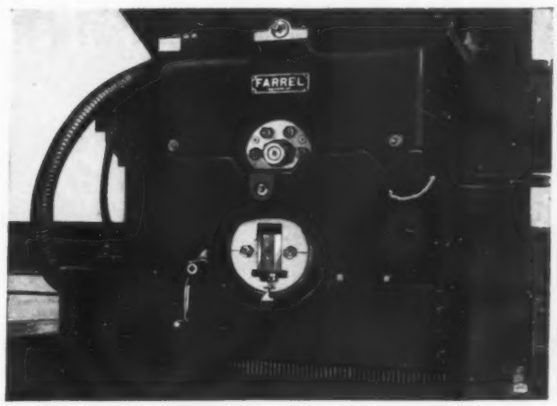
National Steel now has capacity to produce 3,500,000 tons of steel annually, being tied for fourth place in the industry in the matter of production.

NEW METHOD OF PRODUCING TINPLATE

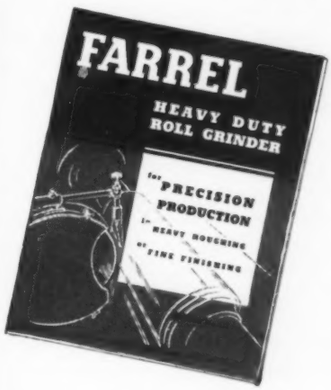
▲ The U. S. Patent Office, issued to Blaw-Knox Company a patent on a method of producing tin plate. According to an officer of the company this method makes it possible to produce a sound adherent tin coating with the use of less tin than is required by previously used methods.

The scope of the patent is indicated by the following allowed patent claims. "In a process for producing tin plated steel strip, heating the strip to a temperature sufficiently high to anneal and temper the same, gradually cooling said strip while preventing contact with external air, joining portions of strip end to end to form continuous strip with good electrical contact at the joint, and moving the continuous strip uninterruptedly and at a substantially constant speed through the sequential operations of acid pickling, washing, electroplating in a tin bath in which the moving strip constitutes the cathode and passes between anodes distributed along the submerged portions of the strip, washing, and drying, said operations thus producing steel strip coated with an adherent and evenly distributed electro deposit of tin."

The patent is issued to the company on application of John S. Nachtman, who is now associated with the Electrochemical Processes Division of the Blaw-Knox Company.



AUTOMATIC, ACCURATE, SYMMETRICAL ROLL CROWNING *and* CONCAVING



Farrel Heavy Duty Roll Grinders have many other important features which contribute to superior performance, better finish and increased output. Send for a complimentary copy of Bulletin No. 111 which tells about them.

The Farrel crowning and concaving attachment produces a mathematically accurate curve of correct shape for either a crowned or concaved roll, exactly symmetrical on both halves of the roll. The same setting invariably produces exactly the same curvature and permits fixed, uniform and easily controlled accuracy of contour in all rolls.

The device is the adjustable, single eccentric type, built into the wheel head at the rear of the carriage, the design and construction of the mechanism assuring exact synchronism between the wheel carriage and wheel when crowning or concaving a roll. It is designed for ease and simplicity of setting and to produce the exact curvature required. The eccentric and change gears are readily accessible so that settings for any curve can quickly be made.

FARREL FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN.
New York • Buffalo • Pittsburgh • Akron • Chicago • Los Angeles

NEW LITERATURE

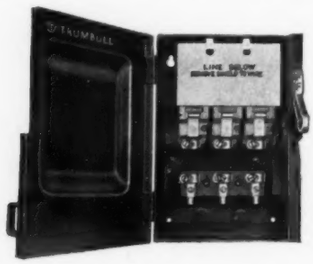
▲ Metal and Thermit Corporation has prepared a booklet describing the Thermit welding process and its applications. Far more complete than anything published previously on the subject, the new booklet gives the history of Thermit welding; describes the nature of the reaction, by means of which superheated liquid steel is produced for welding purposes; discusses the physical properties of weld metal; and outlines the methods employed in welding.

Copies of this bulletin may be had by writing the Metal and Thermit Corporation, 120 Broadway, New York, New York.

▲ Link-Belt Company has published a 12-page book, complete with engineering data for figuring applications, covering the new line of Link-Belt Shafer radial-thrust single-row and double-row roller bearings, in the naked or unmounted form. The new booklet gives dimensions, weights, load ratings at 500 rpm., and list prices, for both single-row and double-row bearings.

A copy of this book No. 1652 may be obtained by writing to Link-Belt Company, 307 North Michigan Avenue, Chicago, Illinois.

▲ Trumbull Electric Manufacturing Company has available a supply of booklets describing their new "RBA" safety switch. This new Trumbull switch supersedes the old "RB" line, retaining all its notable advantages, with several new features of real significance. Some of these new features, as described in the booklet, are as follows: Interior mounted on a removable saddle; a convenient operating handle; a heavy cover



catch and releasable interlock; wiring gutters; solderless connectors; and, newly designed enclosures. These new features together with the many others which gave distinctive merit to the "RB", guarantee for the new "RBA" mechanical and electrical strength that will enable it to render unusually long service under severe operating conditions.

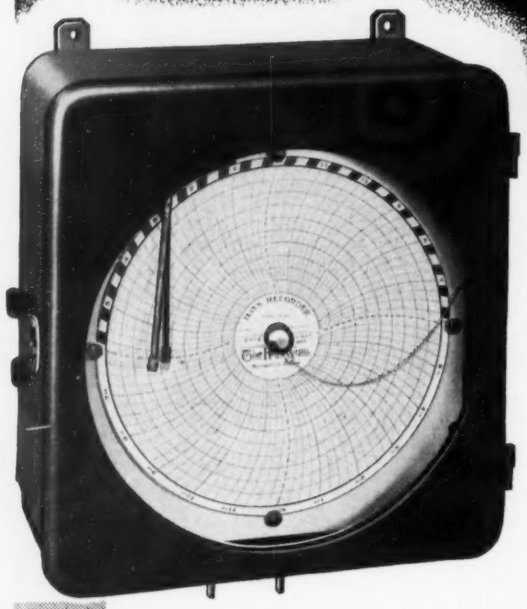
Copies of this circular, No. 300, can be obtained by writing the Trumbull Electric Manufacturing Company, Plainville, Connecticut.

▲ Morgan Engineering Company has prepared an attractive catalogue on ladle cranes. Amply illustrated throughout, this 36-page book gives detailed descriptions of various types of ladle cranes manufactured by this company. Also included is a description of one of the most notable and important improvements, the Morgan compensating device for equalizing the load on two hoisting motors.

If you desire one of these books, which has been arranged in a manner that is suitable for permanent filing, write to the Morgan Engineering Company, Alliance, Ohio, requesting Ladle Crane Bulletin No. 23-A.

FURNACE ATMOSPHERES *Accurately Checked*

HAYS "OT" DRAFT RECORDER



In the steel industry the HAYS Super-sensitive OT Draft Recorder is invaluable for maintaining proper atmospheres in soaking pits, annealing furnaces, open hearth furnaces, slab-mills—any place where an accurate record of Draft, Pressure or Differentials is required. Sensitive enough to register accurately increments of .0025 of an inch water pressure yet husky enough to withstand the jars and dirt of mill operation. Cut shows case for lug mounting on wall; made also for flush panel mounting and with carrying handle for spot testing. Measuring unit is the famous Hays Slack-leather Diaphragm—fool proof, long lasting. Two draft values, two pressure values, two differential values or a combination of any two of these three values may be recorded. Or a temperature recorder may be substituted for one of these values. Send for descriptive literature. Write Dept. 7-8-8.

The HAYS CORPORATION

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FOR ITS HEAVIEST LOADS

STEEL PICKS PENOLA

FIRST place in steel mill lubrication ... because it handles steel's toughest jobs and heaviest loads, Penola makes and sells more steel mill lubricants than any other company in the world. When the life of costly machinery is at stake ... when vital machines must be kept running smoothly and efficiently under shock loads and high temperatures ... steel picks Penola Extreme Pressure Lubricants. Over 85% of all continuous-mill roller bearings in use today are Penola lubricated.

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PENOLA INC., PITTSBURGH, PA.

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LUBRICANTS FOR THE STEEL INDUSTRY SINCE 1885.

ADVERTISING PAGES REMOVED

ITEMS OF INTEREST

Foster McGraw, Forest Barnes, Edgar Tipton, Tom Reynolds, James Neill, Robert Funston, John Fuller, and Richard Getter, of the American Rolling Mill Company, Middletown, Ohio, sailed for England July 20. These men will assist in solving problems connected with starting the new continuous strip mill at Ebbw-Vale (Wales) plant of Richard Thomas and Company, Ltd., an associate of the American Rolling Mill Company, scheduled to begin operations next month. S. E. Graeff, former assistant general superintendent at the Armco East Works in Middletown, Ohio, is assistant manager of the Welsh plant.

▲

Fred Gage, superintendent of Consolidated Works of the American Steel and Wire Company, has retired from active service in that capacity. Mr. Gage, who has climaxed 46 years of service with the company, was first employed as a clerk for the Washburn & Moen Manufacturing Company, in August 1892, and when that company was absorbed by the American Steel and Wire Company, he remained and worked successively as assistant superintendent at Donora, Pennsylvania, superintendent at Farrell, Pennsylvania, and superintendent of the Consolidated works, Cleveland, Ohio.

▲

R. C. Helm, superintendent of the American Steel and Wire Company's Trenton, New Jersey, works, has been transferred to Cleveland as superintendent of the Consolidated Works, where he succeeds Fred Gage who has retired.

▲

E. J. Reardon, previously superintendent at the American Steel and Wire Company's New Haven, Connecticut, plant, has been made general superintendent of that plant and the Trenton Works. In addition to the supervision of these plants, Mr. Reardon's duties will include supervision and direction of wire rope engineering, bridge engineering, etc. He will be located at New Haven, Connecticut.

▲

S. B. Metcalf, who has been general foreman of the rope department at New Haven, becomes superintendent of the American Steel and Wire Company plant at Trenton, New Jersey. R. Murray, previously general foreman of the wire department at New Haven, becomes assistant superintendent of the New Haven Works.

▲

Ralph Nolan has been appointed as representative for the furnace division of the Continental Roll and Steel Foundry Company, in the southern district. Mr. Nolan will be located in the Citizens and Southern National Bank Building, Atlanta, Georgia, where he will handle the sales and engineering of industrial combustion equipment and allied furnace accessories manufactured by this division of the company.

Edward S. Coe, Jr., has been assigned to the Chicago branch sales office of Farrel-Birmingham Company, Inc., located in 1059 First National Bank Building, Chicago, Illinois. Mr. Coe, who has spent several years in the sales engineering department of the Buffalo plant, has been assigned to the Chicago area to promote the sales of Farrel-Sykes herringbone gears and gear units, which are manufactured at the company's Buffalo plant.

Born in Worcester, Massachusetts, Mr. Coe attended the public schools of that city, and received his engineering education at Worcester Polytechnic Institute, graduating in 1931. After graduation Mr. Coe was associated with American Steel and Wire Company, and Reed-Prentice Company before joining the Farrel-Birmingham organization at Buffalo as sales engineer.

▲

Donald C. Bakewell, a vice-president of the Blaw-Knox Company, was elected a director of the company at the last meeting of the Board of Directors. Mr. Bakewell became affiliated with Blaw-Knox Company early in 1937, being engaged in a sales capacity, and was elected a vice-president on June 22, 1937.

Mr. Bakewell graduated from Yale with the class of 1908 and took post graduate training at the Massachusetts Institute of Technology. His business experience has been in the steel manufacturing field and allied lines, involving the presidency of a local steel foundry, and for a term of ten years, the presidency of a local forging company. Immediately prior to joining Blaw-Knox Company, Mr. Bakewell was first vice-president of a western roll and machine company.

▲

Homer Kendall has been appointed to handle special engineering problems in sales work with Salem Engineering Company, Salem, Ohio. Mr. Kendall's experience in designing and building special handling equipment for industrial furnaces, all types of crane work, and in the forging industry, furnishes an admirable background for the special engineering work in which he will be engaged. Mr. Kendall, formerly associated with the Alliance Machine Company, is well-known in the fields where he has been formerly active.

▲

Robert E. Brown was appointed as representative, of the Ohio Electric and Manufacturing Company in the Pittsburgh territory, for the sale of Ohio lifting and separation magnets. Mr. Brown will maintain headquarters at 311 Ross Street, Pittsburgh, Pennsylvania.

▲

J. L. Shakely has been elected president of Frick-Reid Supply Corporation, the oil country subsidiary of the Jones and Laughlin Steel Corporation. Mr. Shakely has been vice president of Frick-Reid's operations in the west. His headquarters will be in Tulsa, Oklahoma.